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Apparent Resistance to the Spotted Alfalfa Aphid Selected from Seedlings of Susceptible Alfalfa Varieties[1]

T. L. HARVEY and H. L. HACKEROTT,[2] *Fort Hays Branch, Kansas Agricultural Experiment Station, Hays*

The spotted alfalfa aphid[3] is of considerable economic importance in the United States. It was described by Smith *et al.* (1956) as the worst pest of alfalfa ever to reach California. The first records of its appearance in this country were from Arizona, California, and New Mexico during the spring of 1954. (Dickson *et al.* 1955). The rapid spread of this insect is indicated by the report that this aphid was found in 14 states by the end of 1955. (Smith *et al.* 1956). The spotted alfalfa aphid was first found in Kansas during August 1954, and by October 1955, it had been collected in all areas of the state. Descriptions of the extensive damage caused by this aphid to alfalfa were reported from Arizona by Tuttle & Butler (1954) and from California by Parker *et al.* (1956). A number of insecticides have proved to be effective in controlling the spotted alfalfa aphid (Tuttle & Butler 1954, Reynolds & Anderson 1955); however, control has often been difficult to maintain because of reinfestation from neighboring fields. The desirability of developing a variety of alfalfa resistant to the aphid is evident.

Apparent differences among alfalfa varieties in reaction to the spotted alfalfa aphid was reported by Harpaz (1955). Stanford (1955) indicated that this aphid could not survive on the variety Lahontan, and Reynolds & Anderson (1955) stated that it was exceedingly injurious to all commercial varieties of alfalfa in California except Lahontan.

The present investigation was made to determine the possible value of selecting plants for resistance in the seedling stage and to compare methods of evaluating resistance. Since the degree of adaptation of the variety Lahontan in Kansas is unknown, efforts were concentrated on obtaining resistant plants from the adapted variety Buffalo.

MATERIALS AND METHODS.—Alfalfa seedlings were screened for resistance to the spotted alfalfa aphid in the greenhouse at an average temperature of approximately 75° F. These seedlings consisting of eight varieties were established by planting about 200 seeds per row in 20-inch square flats of nine rows each in a completely randomized design as follows: Buffalo, 150 rows; Ranger, Ladak, Grimm, Nomad, Meeker Baltic, and Cossack, three rows each; and 12 check rows of the resistant variety Lahontan.[4] One week after the plants emerged a stand count was made and the seedlings were infested by scattering large numbers of aphids on the plants and soil in each flat. All alfalfa plants of susceptible varieties that survived 1 month after infestation were transplanted into pots.

When the plants selected for resistance had become established in pots after being transplanted from flats, they were compared for resistance with Buffalo and Lahontan check plants. In this test, 160 Buffalo plants selected for resistance were compared with 10 randomly selected Lahontan and 10 randomly selected Buffalo plants. All plants were infested by scattering 50 to 100 aphids on the plant and soil in each pot, and the plants were rated for resistance 2 weeks after infestation. The ratings were based on the numbers of aphids present and the degree of injury to the plant.

In a second test the resistance of nine plants which were previously rated good after being infested with 50 to 100 aphids were compared with nine randomly selected Buffalo and nine randomly selected Lahontan check plants of comparable size by a caged-leaf technique. This method consisted of caging 20 fourth-instar nymph or adult aphids on each of three separate randomly selected leaves per plant. The cages were constructed by closing one end of a 3-inch section of dialyzing tubing 1 inch in diameter. After the aphids were placed in the cage, the leaf to be tested was inserted through the open end of the tube and secured around the petiole with a hair pin. The leaves remained attached to the plant and no attempt was made to place the aphids directly on the leaves. The adults and nymphs present on the enclosed portion of the plant were counted each day after infestation for 5 days. Since the tubing was transparent the aphids were counted without removing the cage. A small flashlight facilitated counting the small nymphs.

RESULTS—In screening alfalfa seedlings for resistance, 209 Buffalo plants survived from approximately 25,000 seedlings. In addition, 1 to 10 plants survived from about 500 seedlings each of the following six varieties tested:

PAID PAPER.

[1] Contribution No. 101, Fort Hays Branch Experiment Station and Contribution No. 659, Department of Entomology, Kansas State College. Accepted for publication March 29, 1956.

[2] Assistant Entomologist and Assistant Agronomist, respectively, Kansas Agricultural Experiment Station.

[3] This aphid has been confused with the yellow clover aphid, *Myzocallis trifolii* (Monell) in some of the earlier literature, now called *Pterocallidium trifolii* (Monell). Although authorities on aphid taxonomy do not agree on the scientific name, recent publications by Harpaz (1955), Reynolds & Anderson (1955), and Dickson *et al.* (1955) have used *Therioaphis maculata* (Buckton). It is also called *Pterocallidium* sp.

[4] Lahontan seed supplied by E. H. Stanford, Department of Agronomy, University of California, Davis.

Ranger, Ladak, Grimm, Nomad, Meeker Baltic, and Cossack.[5] In contrast, it appeared that only a small percentage of the Lahontan seedlings were killed by aphids. The exact number of plants destroyed by aphids was not determined because a few plants succumbed to damping-off after stand counts were made. Furthermore, it appeared that all of the 209 plants which survived may not have been resistant since 49 plants failed to become established in pots possibly because of aphid injury which occurred previous to being transplanted.

The results of rating plants for resistance after the plants were infested with 50 to 100 aphids each are presented in table 1. In this test 160 Buffalo plants which were selected for resistance were compared with randomly selected Buffalo and Lahontan check plants. Two weeks after the plants were infested the 10 Buffalo check plants were killed by the aphids. On the other hand, 10 Lahontan check plants survived and all except one supported less than 10 aphids per plant. Likewise, none of the 160 Buffalo plants selected for resistance were destroyed by aphids during this period; however, the level of resistance appeared to vary from good to poor as indicated by aphid populations and plant injury. Plants which were rated good appeared to be as resistant to the aphids as the Lahontan check plants which were rated good for resistance. A similar evaluation of 28 plants selected for resistance from the other six susceptible varieties tested indicated that these plants possessed a level of resistance comparable to that reported for plants selected from the variety Buffalo.

Data obtained by the caged-leaf method are presented in table 2 comparing the resistance of the following three classes of plants: nine Buffalo plants rated as good for resistance in table 1, nine plants randomly selected from the susceptible variety Buffalo, and nine randomly selected plants from the resistant variety Lahontan. The daily mean numbers of adult and nymph aphids for both resistant classes appeared to be quite different from the means of the susceptible class from the second to the fifth day inclusive. On the other hand, there were no marked differences among mean numbers of aphids for the resistant Buffalo selections and the resistant Lahontan variety for any of the 5 days. The mean number of aphids for the two resistant classes progressively decreased during the 5-day period while the means for the susceptible class more than doubled by the third day.

[5] R. H. Painter and Don C. Peters of the Department of Entomology, Kansas State College, observed resistance in a small percentage of plants of Buffalo Ranger, Kansas Common, Ladak and Atlantic in tests at Manhattan.

Table 1.—Numbers of plants of Buffalo alfalfa selected for resistance and randomly selected Buffalo and Lahontan check plants classified according to degree of resistance to the spotted alfalfa aphid.

Classes of Plants	Total No. Plants	Resistant Rating[a]			
		Good	Fair	Poor	None
		No Apparent Plant Injury		Plants Injured	Plants Dead
Resistant Variety (Lahontan)	10	9	0	1	0
Resistant Selections (Buffalo)	160	99	52	9	0
Susceptible Variety (Buffalo)	10	0	0	0	10

[a] Ratings were based on the presence of the following numbers of adults and nymphs per plant: Good = 0–10, Fair = 11–100, Poor = over 500, None = aphids destroyed plants. The plants were rated at the end of 2 weeks after an initial infestation of from 50 to 100 aphids per plant.

Table 2.—Mean daily numbers of spotted alfalfa aphids per leaf for resistant Buffalo alfalfa selections and randomly selected Buffalo and Lahontan check plants compared by a caged-leaf method.

Classes of Plants	Days After Infestation	Frequency Distribution of Nine Plants of Each Class Based on Mean Number of Aphids per Leaf								Mean[a]
		0–5	6–10	11–15	16–20	21–25	26–30	31–35	36–116	
Resistant Variety (Lahontan)	1		1	4	2	2				16.1
	2	3		2	3	1				11.2
	3	5		2	1				1[b]	5.7
	4	6	2						1[b]	2.4
	5	8						1[b]		1.6
Total		22	3	8	6	3	0	1	2	37.0
Resistant Selections (Buffalo)	1			8	1					13.6
	2	4	3	2						7.3
	3	6	1	1				1		7.3
	4	6	2		1					3.8
	5	8	1							1.9
Total		24	7	11	2	0	0	1	0	33.9
Susceptible Variety (Buffalo)	1			2	4	1	1		1	21.5
	2			2	2	1		1	3	29.2
	3		1[b]			1	1	1	5	52.6
	4	1[b]			1		1		6	60.0
	5	1[b]		1		1			6	60.6
Total		2	1	5	7	4	3	2	21	223.9

[a] Values represent mean numbers of aphids (adults and nymphs) per leaf for three randomly selected leaves per plant which were initially infested with 20 adults or fourth-instar nymphs per leaf.

[b] Subsequent tests utilizing the caged-leaf method indicated that the Lahontan plant was susceptible and the Buffalo plant was resistant. These values were omitted in calculating the means.

The extent of variability for aphid populations on any of the 5 days within each of the three classes of plants is shown in table 2. A large portion of this variability within the Lahontan and Buffalo check plants may be attributed to one Lahontan and one Buffalo plant which did not agree with the usual ratings of these varieties. Subsequent tests utilizing the caged-leaf method verified that the Lahontan plants was susceptible and the Buffalo plant was resistant.

DISCUSSION.—The results of the data presented indicate that the elimination of susceptible plants in the seedling stage is a practical, rapid method of selecting plants for possible use as a source of resistance to the spotted alfalfa aphid. It appears that a few resistant plants may be present in many alfalfa varieties since a low percentage of plants seemed to be resistant in the seven susceptible varieties tested.

The two tests designed to confirm the presence or absence of resistance in plants selected in the seedling stage seemed to be in agreement. Both appeared to verify the presence of resistance in the selected plants. For the purpose of this study the most practical method was to determine plant reaction and approximate aphid numbers following an infestation with 50 to 100 aphids. A more precise evaluation of resistance could perhaps be made utilizing a method involving more accurate counts of smaller numbers of aphids. However, the caged-leaf method was time consuming and did not appear to be necessary for the practical evaluation of resistance.

In the caged-leaf test only the combined data for nymphs and adults are presented; however, the ratio of nymphs to adults appeared slightly higher for leaves of susceptible plants than for leaves of resistant plants. This ratio would possibly have been greater except that there was a tendency for nymphs to drop from the leaves, and in the case of the susceptible plants the nymphs became trapped in the honeydew which collected on the bottom of the cages. It appeared that it would have been possible to distinguish between the resistant and susceptible plants by the varying amounts of honeydew that collected in the cages.

In analyzing plants for resistance it has been useful to divide the mechanisms of resistance into three categories described by Painter (1951) as preference, antibiosis, and tolerance. The two methods used to determine the presence or absence of resistance in plants which were selected for survival in the seedling stage indicated that antibiosis and/or preference were responsible for resistance possibly in addition to tolerance.

Progeny tests of seedlings from the plants selected for resistance will determine the extent to which the resistance present in these Buffalo selections can be effectively utilized in a breeding program. In addition, it will be necessary to confirm the resistance of these plants under field conditions.

SUMMARY.—Alfalfa plants which appeared to be resistant to the spotted alfalfa aphid were readily isolated from susceptible varieties by selection of surviving plants following infestation in the seedling stage. Resistance of plants selected in the seedling stage were evaluated by determining plant reaction and aphid populations after infestation with from 50 to 100 aphids and by utilization of a caged-leaf technique. These tests indicated that the degree of resistance in the selected plants varied. However, plants were selected which appeared to have a level of resistance comparable to that present in resistant plants of the resistant variety Lahontan.

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Studies on the Legume Mite, *Petrobia apicalis*[1]

ELSAYED AHMED ZEIN-ELDIN,[2,3] *Zoology Department, University of Iowa, Iowa City*

Petrobia apicalis (Acarina: Tetranychidae) was first described by Banks (1917) who named it *Tetranychina apicalis*, and redescribed by McGregor (1950) under the latter name. In their revision of the family *Tetranychidae*, Pritchard & Baker (1955) changed the name of the genus from *Tetranychina* to *Petrobia*. This mite has recently become a serious pest of legumes and clovers in Louisiana. It is probably distributed throughout the Gulf States and as far north as Missouri. The occurrence, seasonal habits, and control of *Petrobia apicalis* were studied by Smith & Weber (1954), who gave it the common name "legume mite." They reported the life cycle to have an active stage during the cooler months of the year (November–February) and an inactive stage starting in March and lasting through the summer and early fall. The latter stage takes place in the form of diapause eggs which hatch when the weather conditions become favorable, usually following a heavy rainfall and a drop in temperature. This paper deals with three main points: (1) the life history, (2) termination of diapause in the egg, and (3) evocation of diapause egg laying in the female.

MATERIALS AND METHODS.—The mites were reared on

[1] These data are taken from a dissertation submitted in partial fulfillment of the requirements for the Ph.D. degree in Zoology at the State University of Iowa. Accepted for publication October 26, 1955.

[2] The author is indebted to Dr. H. B. Boudreaux of Louisiana State University for his suggestion of this problem and for permission to use equipment and laboratory facilities.

[3] Present address: College of Agriculture, University of Cairo, Giza, Egypt.

white clover, *Trifolium repens* L., using Boudreaux's technique (unpublished). Clover leaves with a piece of rhizome and some roots were detached singly from healthy plants brought from the field into the laboratory. The rhizome and roots were then passed through a short rubber tube fixed in a central hole in a petri dish, and with the aid of a cotton plug the petiole of the leaf was held in the rubber tube. Commercial tree tanglefoot was applied to the petiole, around the upper rim of the rubber tube, and around the rim of the petri dish. Dishes were then transferred to lighted cabinets. The rhizomes were passed through holes in the upper shelf of the cabinet into tap water in bottles on the lower shelf of the cabinet. The mite cultures were individually covered with high petri dish covers. The light intensity inside the cabinets ranged from 75 to 150 f.c. The life history was studied at two temperature ranges: 58 to 60° F. (cold room) which approximates the winter temperature in Louisiana, and 78 to 86° F. (warm room) to test the survival ability of the mite at high summer-like temperature. Daily photoperiods of 8 and 16 hours were used in the cold room, while 10 and 24 hours were used in the warm room.

The hatching of diapause eggs was carried out in petri dishes. Twigs, bark, or other wooden objects infested with a known number of diapause eggs were placed in a small petri dish, the rim of which was covered with tanglefoot to trap the larvae and facilitate the determination of percentage of hatching. The small dish in turn was placed in an ordinary petri dish with two layers of filter paper saturated with KOH solutions of various concentrations to provide known levels of relative humidities (Peterson 1953). The larger dish was covered by another of the same diameter and the entire device sealed off with scotch tape. Eight such devices with 100%, 95%, 90%, 80%, 70%, 60%, 40%, and 20% relative humidities were incubated at 58 to 60° F., while another set of eight was incubated at 78 to 80° F. to determine the conditions capable of breaking the diapause. In another attempt to break the diapause, eggs were treated with xylol for 1, 2, 3, 5, 10, 15, 20, and 25 minutes, thoroughly dried and incubated at 58 to 60° F. and a relative humidity of 95%. Natural breaking of diapause in the field in November was also studied and correlated with prevalent weather conditions and compared with laboratory results.

The roles of three environmental factors in evoking diapause egg laying in the female were studied: namely, photoperiod, nutrition and temperature (Lees 1953a, 1953b).

RESULTS AND DISCUSSION.—The life history of *Petrobia apicalis* is composed of five stages. These are: the non-diapause or the diapause egg; larva; protonymph; deutonymph; and adult. Each immature stage other than the egg moults only once.

The Diapause Egg.—This egg (Fig. 1A) is composed of a white rigid cup-shaped receptacle full of cherry red embryonic material securely covered with a lid (Fig. 1B). The receptacle has 20 to 30 superficial longitudinal sections, each of which corresponds to a radial section on the lid. The average egg measures 191×157 microns. The embryonic stage at which the egg enters diapause was not determined. When diapause is broken and development completed, the larva presses against the lid and forces its way out. The hatch from diapause eggs gives a sex ratio of approximately 1:1. This indicates that almost all females laying diapause eggs have been fertilized since unfertilized females produce only males.

The Non-Diapause Egg.—This egg (Fig. 1C) has a pearly transparent and minutely striated shell containing the cherry red embryonic material which gives the egg its color. The egg is almost hemispherical, with a straight finely wrinkled and sticky base. The average egg measures 177×127 microns, and has a small depression in the top center. Non-diapause eggs are usually deposited on the underside of the leaf; along the midrib and veins or in depressions among the veins close to the edge of the leaf. Embryonic development, the details of which were not determined, lasts for an average of 14 days in the cold room and 3.8 days in the warm room. As the embryonic development progresses, the eggs gradually become darker, and by the end of the first two-thirds of the incubation period, they are dark brown. During the last third of the incubation period, however, the eggs gradually lighten until immediately before hatching they become scarlet red. The process of hatching follows the pattern described by Baker & Wharton (1952). Fertilized females laying non-diapause eggs produce a sex ratio of approximately 1:1.

The Larva.—The hexapod larva (Fig. 2A) averages 285×196 microns and has a soft globose and scarlet body. Male and female larvae cannot be differentiated. The larval integument is striated with broken (dotted) lines chacteristic of all stages in the life cycle. Most striae are transverse, but they can be tortuous. A weak suture on the dorsum separates the propodosoma from the hysterosoma. The propodosoma has three pairs of dorsal setae: frontal; subfrontal; and humeral, the first pair being approximately three times as long as the others. One perfect and one imperfect red eye cornea are located on each side between the subfrontal and the humeral setae. The hysterosoma has 10 pairs of dorsal setae: three dorsocentrals, three dorsolaterals, one humeral, two sacrals, and one clunal. The sacral setae are approximately three times as long as any of the hysterosomals, and originate from prominent tubercles. All dorsal setae are setose. The ventral setae are distributed: two pairs near coxae I and III, and three pairs of anals and two pairs of postanals in the anal region (Fig. 2B). All these ventral setae are simple. The peritremes, stylets, and palps are well developed. The larva is the only stage in the life cycle which is capable of spinning a fine web, the source of which is probably located in the thumb of the palp (Grandjean 1948). The larva starts feeding immediately after hatching, and its scarlet color soon darkens, eventually becoming dark greenish-brown. The feeding punctures arranged in

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FIG. 1.—A. Diapause egg (side view); B. Lid of diapause egg (top view); C. Non-diapause egg (side view).

FIG. 2.—A. Dorsoventral view of larva; B. Anal region.

FIG. 3.—A. Dorsoventral view of protonymph; B. Anal region.

FIG. 4.—A. Dorsoventral view of deutonymph; B. Anal region.

FIG. 5—A. Dorsoventral view of male; B. Genitoanal region.

FIG. 6.—A. Dorsoventral view of female; B. Genitoanal region.

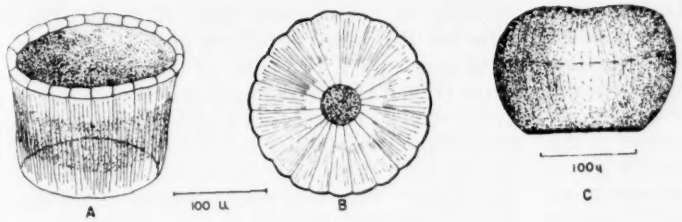

FIG. 1

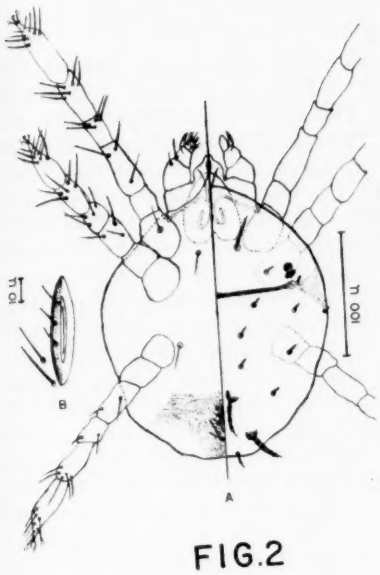

FIG. 2

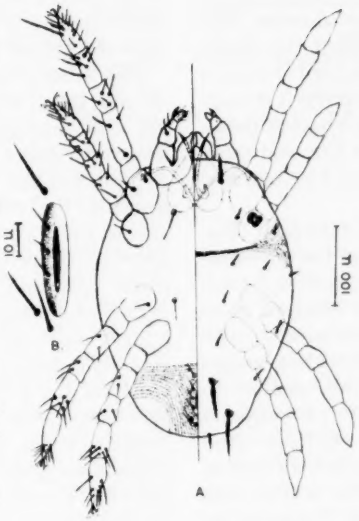

FIG. 3

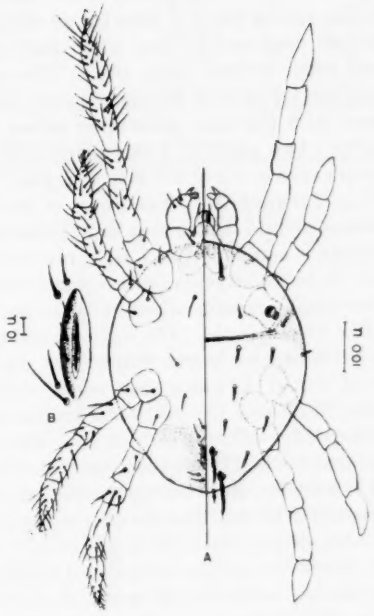

FIG. 4

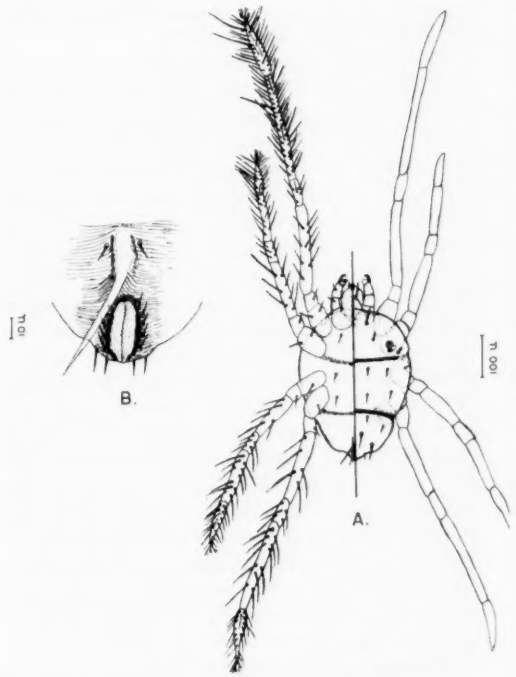

FIG. 5

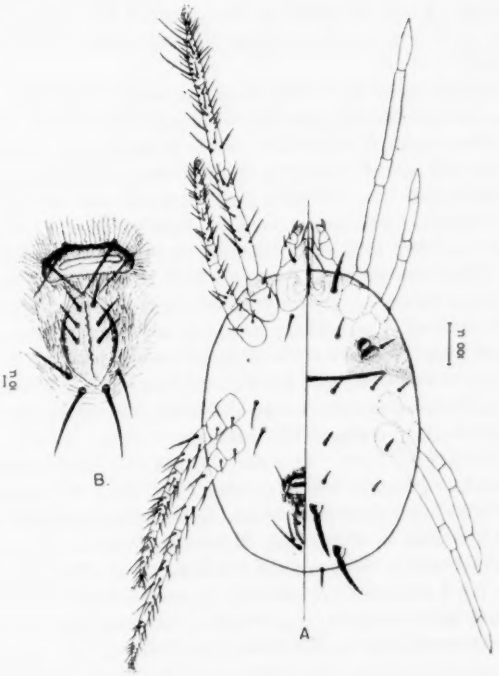

FIG. 6

straight, bent, or criss-cross lines are helpful in the recognition of the infestation in the field. Feeding is done almost exclusively on the top side of the leaf. The feeding period lasts for an average of 4 days in the cold room and 0.8 day in the warm room. At the end of the feeding period, the larvae become sluggish, seek depressions on the top side of the leaf and settle down into a state of quiescence. The quiescent period which occurs exclusively on the top side of the leaf lasts for an average of 3.7 days in the cold room and 0.7 day in the warm room. This period ends when ecdysis takes place. The mite loosens itself from the larval skin which becomes pearly white. A few hours later the skin splits open across mid-dorsum. The anterior two pairs of legs emerge first, then the protonymph crawls out of the skin dragging the hind two pairs of legs forward. In other mites of the family Tetranychidae the hind legs emerge first (Baker & Wharton 1952). Ecdysis is completed in 1 to 3 minutes in the cold room and 15 to 20 seconds in the warm room. The moulted skins usually remain adherent to the leaf.

The Protonymph.—The eight-legged protonymph (Fig. 3A) develops its fourth pair of legs during the quiescent larval period. It has a soft, ovoid, dark greenish-brown body. Male and female protonymphs are identical morphologically, differing only in size. The male protonymph averages 365×239 microns whereas the female averages 481×306 microns. Integumental striae are similar to those of the larvae. The dorsal features of the protonymph are also identical with those of the larvae. On the ventral side, however, one pair of preanal simple setae, missing in the larvae, is formed immediately anterior to the anus (Fig. 3B). The protonymph spins no web. Immediately after emerging from the larval skin, the protonymph begins to feed. The feeding period, as well as the quiescent period following it, each lasts for an average of 2 days at 58 to 60° F. and 0.6 day at 78 to 86° F. Feeding, quiescence, and ecdysis almost always occur on the top side of the leaf.

The Deutonymph.—This stages averages 588×358 microns for the female and 448×275 microns for the male. The deutonymph is similar to the protonymph in color, shape, and dorsal view (Fig. 4A). However, it differs conspicuously in the ventral aspect. A third pair of ventral body setae is formed near coxa IV. Another pair of preanal setae is added, making a total of two preanal pairs (Fig. 4B). The deutonymph spins no web. Immediately after emerging from the protonymphal skin, the deutonymph starts to feed. The feeding period as well as the quiescent period which follows it, each lasts for an average of 1.7 days at 58 to 60° F. and 0.5 day at 78 to 86° F. Ecdysis in the male deutonymph occurs about 6 hours earlier than in female deutonymphs of the same age.

The Adult Male.—The male's body is ovoid with a somewhat pointed posterior end (Fig. 5A). It averages 544×255 microns in size, which shows no appreciable gain over the male deutonymph. However, there is a tremendous increase in the length of the male's legs. For example, male leg I averages 890 microns as compared to the counterpart in the deutonymph which measures 388 microns. The hysterosoma is subdivided in two regions: a metapodosoma carrying the anterior two dorsal rows of hysterosomal setae (five pairs), and an opisthosoma with the five posterior pairs. The sacral setae, longest of the hysterosomals, do not originate from tubercles. The ventral setae are distributed as follows: one pair on the propodosoma near coxa I, two pairs on the metapodosoma near coxae III and IV, one genital pair at the base of the aedeagus averages 75 microns in length. Apparently the adult males display less feeding activity than any other stage in the life cycle. This may explain their light or yellowish brown color. They feed predominantly on the top side of the leaf. The male is capable of fecundation immediately after emerging from the deutonymphal skin. Copulation takes place as described by Baker & Wharton (1952) for other genera of the family Tetranychidae. The adult male's longevity averages 36 days at 58 to 60° F. and 15 days at 78 to 86° F.

The Adult Female.—The body is ovoid and frequently oblong (Fig. 6A), reddish dark brown and averages 942×587 microns. The dorsal view is similar to that of the immature stages. The ventral aspect resembles the deutonymph, but the two preanal pairs of setae have become genitals (Fig. 6B). The females usually feed on the top side of the leaf. There are two types of females with respect to egg laying: females which lay only red non-diapause eggs, and females which lay only white diapause eggs. The female laying non-diapause eggs passes through a preoviposition period which starts immediately after the emergence from the deutonymphal skin and ends with the laying of the first egg. The duration of this period averages 8 days at 58 to 60° F. and 0.7 day at 78 to 86° F. The period between the laying of the first and last egg is the oviposition period and lasts for an average of 33 days at 58 to 60° F. and 11 days at 78 to 86° F. The average total number of eggs per female is 197 at the former temperature range and 164 at the latter. The postoviposition period lasts for an average of 12 days at 58 to 60° F. and 4 days at 78 to 86° F. before the female dies naturally. The longevity of this type of female averages 54 days at 58 to 60° F. and 17 days at 78 to 86° F.

The female laying diapause eggs has an average preoviposition period of 10 days, an oviposition period of 23 days and a post oviposition period of 15 days when reared at 58 to 60°. The respective periods for females raised at 78 to 86° F. average 1 day, 12 days, and 4.5 days. The average total number of eggs per female at low temperature is 77 eggs and at high temperature the number is 72. The longevity of this type of female averages 46 days at 58 to 60° F. and 17 days at 78 to 86° F. There is no morphological difference between the females laying diapause and laying non-diapause eggs. In some genera of Tetranychidae a solid form of striae (unbroken lines) was demonstrated on the skin of the females laying diapause eggs (Pritchard & Baker 1952). When this type of female was reared in the laboratory, females were compelled to oviposit on clover leaves and their diapause eggs observed only on the underside or on the groove of the petiole of the clover leaf. When the females fall off the leaf they prefer to oviposit on the rubber tube rather than on the glass dish of the apparatus. In nature diapause eggs are usually laid on tree bark, twigs, marking posts, fences, dry debris, or any rough wooden surface available in the field (Smith & Weber 1954).

Breaking of Diapause in Summer Eggs.—Samples of diapause eggs presumably 4 months old (collected in late July and assumed to have been laid in April) were incu-

bated at 58 to 60° F. or 78 to 80° F. at the relative humidity levels stated under Materials and Methods. The rest of the collection which provided material for later experiments, was maintained in the laboratory at 78 to 86° F. at a relative humidity of 20 to 40%. This group served as controls and remained unhatched. The eggs incubated at 58 to 60° F. hatched only at relative humidities of 80% or higher. Eggs incubated at 78 to 80° F. did not hatch at any level of relative humidity that was applied. This indicates that diapause can be terminated by the use of simultaneous low temperature and high relative humidity. Later experiments showed that diapause eggs require storage at high temperature and relatively dry atmosphere, i.e. 80° F. and 20 to 40% relative humidity, for a period of 2 to 3 months after laying before low temperature and high humidity can break the diapause. The period required for breaking of diapause could not be separated from the period of embryonic development. This was due to the lack of knowledge of the constituents of the diapause egg. Therefore, the two periods will be collectively referred to as the incubation period. When diapause was broken during August through early November, the incubation period ranged from 28 to 32 days and the percentage of hatch ranged from 93 to 98%. As the eggs grew older the incubation period became longer and the percentage of hatch declined. In late November and early December the incubation period ranged from 31 to 38 days and the percentage of hatch from 62 to 80%. In late December and January, the incubation period ranged from 34 to 40 days and the percentage of hatch from 39 to 50%. In February, the former ranged from 35 to 42 days and the latter from 20 to 30%. In March, the eggs kept as controls started to dry up and their lids started to fall off. Apparently, the eggs became non-viable when kept for 12 months after oviposition under summer-like conditions of temperature and humidity.

A comparison of the laboratory-controlled experiments and the effects of the uncontrolled weather conditions on the diapause eggs in the field was made. The eggs were placed beside a weather station in the Louisiana State University farm until they hatched. The weekly mean temperature and relative humidity during the incubation period were computed graphically (Askovitz 1955) from the records of the weather station. The dates and percentages of hatching as well as the weather conditions are given in table 1. The last column in table 1A, shows that relative humidities higher than 90% had prevailed for about one-half the total period of incubation. This indicates that there is no necessity for continuous maintenance of the high relative humidity throughout the incubation period. However, this factor may be the primary stimulus in the breaking of diapause since the drop in temperature to an average of 65° F. did not occur until later (during the week starting October 11). This week was probably the time when development started. If this assumption is true then the incubation period ending on November 7 (Table 1B) was 28 days which is almost identical with that obtained in the laboratory in early November (28 to 32 days). These field observations may be of some value in developing control measures against this serious pest. When the first heavy rainfall occurs in early fall, one might anticipate the presence of larvae in the field approximately 4 weeks after the temperature drops to an average of about 65° F. or below. During this time control measures could be taken to combat the larvae before they cause appreciable damage to their hosts.

Table 1.—Breaking of Diapause in *Petrobia apicalis* in the Field.

A. Weather Conditions during Development

Week	Temperature, Degrees F.		Per Cent Relative Humidity		
	Range	Mean	Range	Mean	Total Hours over 90
9/27–10/3	68–90	78	40–99	77	108
10/4 –10/10	63–89	75	40–99	76	102
10/11–10/17	44–88	65	19–99	68	86
10/18–10/24	46–80	64	22–99	60	68
10/25–10/31	37–82	60	24–99	72	94
11/1 –11/7	34–72	51	22–99	64	58
11/8 –11/14	46–74	60	24–99	68	58

B. Dates and Percentages of Hatching

Date November, 1954	Per Cent Hatching
7	51.7
8	24.1
9	11.2
10	7.7
11	0.0
Total	94.7

The fat solvents proved to be successful in the breaking of diapause in the eggs of the mite, *Metatetranychus ulmi* Koch (Dierick 1950). In view of Dierick's work, the possible effects of xylol on the diapause eggs of *Petrobia apicalis* were investigated. In three experiments conducted in early fall, eggs were treated with xylol as specified under materials and methods, dried, and incubated at 58 to 60° F. and 95% relative humidity. Development occurred only in the eggs submerged in xylol for 1, 2, or 3 minutes. Developmental periods averaged 38, 40, and 39 days respectively, while the total percentage of hatch averaged 3%, 2%, and 2% respectively. Non-xylol treated eggs incubated under the same conditions had an incubation period of 28 to 32 days and a 93 to 98% hatching rate. Apparently, the diapause egg receptables are not soluble in xylol, and this fat solvent probably damaged the eggs.

Evocation of Diapause.—Oviposition of winter diapause eggs was initiated in the females of *Metatetranychus ulmi* by subjecting them to low temperatures, short photoperiods, or restricted food supply (Lees 1953a, 1953b). In view of Lees' studies, it is possible that diapause egg laying might be evoked in *Petrobia apicalis* females by subjecting them to high temperatures, long photoperiods, or lack of food. It was found that the females of the first generation emerging from diapause eggs which hatched in September, October, or early November laid only non-diapause eggs at high temperature, i.e. 85 to 90° F. This occurred when the daily photoperiod was 10 or 24 hours, on healthy plants as well as on seriously-injured hosts.[4] All the females of the second generation of this early fall hatch continued to produce non-diapause eggs regardless of any of the three environmental factors. The third generation females, however, produced diapause eggs in 60% of the cases observed. All females of the fourth generation

[4] Investigations by Dr. H. B. Boudreaux, now in progress, may indicate that the nature of food initiates diapause egg laying.

(from the 40% non-diapause eggs of the third generation) produced only diapause eggs. Similar results were obtained when the mites were reared at 58 to 60° F. at either 8 or 16 hours photoperiod on either healthy or injured plants. This might suggest that initiation of diapause egg laying is independent of the three environmental conditions studied by Lees. The females of the late November and early December hatch produced non-diapause eggs in the first and second generations either at 58 to 60° F. or at 78 to 86° F. In the third generation, however, 90% of the females produced diapause eggs in the fourth generation. In later hatchings (late January) diapause eggs were produced by approximately 25% of the first generation females either at low or high temperatures. In this case one-fourth of the females developing directly from the diapause eggs of the preceding year produced diapause eggs. These findings point to a possible relationship between the age of the diapause eggs at the time of their hatching and the initiation of diapause in the females of the progeny of these eggs. In other words, the older the diapause eggs, the less the number of active generations obtained from them and the sooner diapause is initiated in their progeny. Therefore, evocation of diapause may be attributed to certain inherent physiological changes which take place in the females and seem to be dependent, at least in part, upon a cumulative factor. If, through further experimentation, this assumption proves true, then it will probably help in the prediction of the severity of infestation during the active season. When the fall is relatively dry and warm, diapause eggs will hatch later than when there is a cool rainy fall. In the former case, fewer active generations would be expected than in the latter.

SUMMARY.—The mite *Petrobia apicalis* (Banks) is characterized by the oviposition of two kinds of eggs: an active winter egg developing without interruption and a diapause summer egg which must pass a certain period in the inactive state. Diapause was terminated experimentally by subjecting the eggs simultaneously to high ranges of relative humidity (above 80%) and relatively low temperature (58 to 60° F.). Breaking of diapause in the field occurs under similar conditions. Treatment of diapause eggs with xylol does not terminate diapause. Duration and morphological characteristics of the stages in the life cycle are discussed. Conditions under which diapause eggs are oviposited were studied. Initiation of diapause egg-laying in the female may be independent of the environmental factors studied: temperature, photoperiod, and food availability. Inherent physiological changes in the female are suggested to induce diapause egg oviposition.

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Studies of Banana Weevils in Honduras[1]

H. H. V. HORD and R. S. FLIPPIN

Head rot, a disease of banana rhizomes in Honduras (Hord & Flippin 1953), weakens banana rhizomes to such an extent that they break near ground level allowing the above ground portion of the plant to topple over. The break occurs when the crown of the plant becomes too badly decayed to support the weight of the foliage and fruit. The decayed area is invariably riddled by the tunnels of the banana weevil borer. Mature banana weevils and their larvae when taken from diseased tissue and plated out on nutrient agar have been found to carry a heavy population of bacterial contaminants and occasionally fungi. Eggs laid by these beetles obtained from diseased tissue have also been found to carry bacteria. Both the cause of head rot and possible measures of control were investigated. The portion of the studies reported here was undertaken to determine if the weevils act as vectors of the organism causing the decay.

During the progress of the work new information concerning the activities and control of the weevils was discovered. From the weevil traps laid out in banana plantations, it was found that two types of weevils were commonly attracted to cut pieces of banana rhizome and pseudostem. One was the small black weevil commonly called *Gallina ciega* and the other a somewhat larger black weevil with orange or yellow markings on the fore part of the elytra and occasionally on the thorax. The latter, but not the former, was frequently observed to fly. Collections

[1] Investigations by staff members of the Midwest Research Institute, Kansas City, Missouri, for the Standard Fruit and Steamship Company, New Orleans, Louisiana. Accepted for publication October 24, 1955.

of each of these weevils were sent to Miss Rose E. Warner, of the Entomology Research Branch, U. S. D. A. She identified the small black weevil as *Cosmopolites sordidus* (Germ.) and the larger yellow-marked beetle as *Metamasius sericeus* (Oliv.).

At the time these investigations were begun in 1951 the only control method suggested in the literature was that of setting out "traps" made of banana pseudostems. The live weevils had to be removed from the traps daily and killed. Batchelder (1954) demonstrated the effectivity of dieldrin in the control of *C. sordidus* in abaca plantations.

Wolcott (1933) reported that in many localities in Jamaica, *C. sordidus* was so abundant as to be a limiting factor in banana production. He indicated also that no variety of banana or plantain is immune to attack by the weevil though some kinds are more susceptible to injury by it. On the other hand, Edwards (1934) stated that *M. sericeus* does not cause damage to banana plants but is found instead in association with an abundance of plant debris.

VECTOR STUDIES.—Two experiments were set up to determine whether either of the weevils could transmit the disease to healthy plants. At first weevils taken from diseased rhizomes were placed in cones of copper screen tied to healthy rhizomes but the weevils forced their way out around the edges of the cones. In the following trial, cages were made from the lower halves of No. 2 tin cans. Holes small enough to prevent the weevils' escape were punched in the end of each can to permit aeration and the cans sterilized prior to use. Three weevils were placed in each can and the sharp edge of the can pressed into the crown of the plant to a depth of 2 inches leaving a shallow metal cage ½ inch deep to enclose the beetles. Three series, a total of 45 cans, were set out, one series contained three adult *M. sericeus*, in each can; one, three adult *C. sordidus;* and one series of cans was empty. After 5 days the *Metamasius* adults were dead or nearly so whereas the *Cosmopolites* were normally active. At the end of 6 weeks when all were examined not a single case of head rot was found.

A further series was set out, in which 22 cans containing *C. sordidus* adults were placed on the freshly cut surface of banana rhizomes instead of on pseudostems. Negative results were also obtained from this experiment when the rhizomes were examined 6 weeks after exposure.

In laboratory pot experiments, weevils previously caged on head rot tissue for 5 days, soon burrowed down to the healthy seed eyes when placed on pots of soil in which seed eyes were buried. Eggs were laid and larvae developed within 30 days of the time of exposure to weevil attack. In none of the heads, however, was head rot associated with the larval burrows. An extract made from the pulverized bodies of *C. sordidus* that had previously been caged on head-rotted tissue was inoculated into banana rhizomes and potato tubers. None of the 15 inoculations made in banana rhizomes caused head rot during a 22-day incubation period. Identical results were obtained when potatoes were inoculated in a similar fashion.

Attempts to transmit head rot by means of the weevil yielded negative results in all instances. Although there is reason to suppose that weevils could transmit the organism causing head rot, the present experimental work does not support such a supposition. It does, however, indicate that the mere association of weevils from decayed tissue with healthy plants does not insure head rot infection.

THE WEEVILS AS SCAVENGERS.—In order to determine whether or not these weevils occur merely as scavengers feeding on decaying tissue, 100 rhizome traps were set out. These traps were made and set by the method found to be most effective as described later in this paper. Fifty of the traps were cut from healthy rhizomes, the remaining 50 from rhizomes severely attacked by head rot. The paired traps were laid in a row at intervals of 16 feet. The weevils were collected and destroyed every day for 10 days and the trap surfaces freshly cut every third day. The results are presented in table 1.

Table 1.—Weevils trapped on decayed and healthy banana tissue.

Species	Kind of Trap		Total Weevils
	Healthy Rhizomes	Decayed Rhizomes	
Cosmopolites sordidus	366	65[a]	431
Metamasius sericeus	1,049	1,579	2,628
	1,415	1,644	3,059

[a] On sound parts of decayed pieces of rhizome.

The results indicate that there is no basis for the belief that the adult *C. sordidus* prefers decayed tissue.

CONTROL MEASURES.—In order to investigate quantitatively the relationship between the weevil population, the variety of banana, and the application of an insecticide, additional trapping was carried out in mature plantations. Following a serious blow-down on the Calpules farm in September, 1950, in which losses ranged from 50 to 100 per cent, chlordane was applied at monthly intervals in an endeavor to reduce the weevil population. The chlordane, diluted 3 parts to 2000, was applied at the base of the mat through the Bordeaux spray system at the rate of 200 gallons per hectare. The adjacent Rosario farm in which the blow-down was estimated to have caused smaller losses ranging from 10 to 40 per cent, was left unsprayed. The farms were approximately the same age, Calpules being planted in July and August, 1946, and Rosario in January, 1947. The chief difference between the farms was that a higher percentage of Gros Michel plants had been replaced by Bout Rond in Calpules than in Rosario as the result of infection by Panama disease.

While the treatment was not made with the intention of analyzing the results statistically, an attempt was made to salvage all possible information from the area after the treatment had been carried on for a year. In order to do this 200 traps were set, 100 on each farm. Half of the traps on each farm consisted of a piece of pseudostem approximately 18 inches long, cut in half lengthwise. The two sections were put together and laid in the shade at the base of a banana mat. The other half of the traps were cut in a similar manner from rhizomes, a rhizome trap being placed near each pseudostem trap. Twenty-five pairs of these traps were placed on each farm at the bases of neighboring Gros Michel plants. Elsewhere 25 more pairs of traps were placed on an area on each farm that consisted

Table 2.—Weevil counts on rhizome and pseudostem traps 14 days consecutively.[a]

Date of Count	Calpules (Chlordane)								Rosario (No Chlordane)								Total
	Gros Michel				Bout Rond				Gros Michel				Bout Rond				
	Rhizome		Pseudo-stem		Rhizome		Pseudo-stem		Rhizome		Pseudo-stem		Rhizome		Pseudo-stem		
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	
May 30	4	6	2	6	3	5	1	0	59	21	37	10	25	6	18	22	225
31	3	7	0	8	2	4	0	1	64	20	51	19	24	16	13	31	263
June 1	3	6	2	11	7	2	5	0	40	16	14	12	19	27	4	15	183
2	0	1	0	4	0	1	0	0	31	7	8	6	44	11	7	6	126
3	0	0	0	4	0	0	0	0	87	10	22	3	19	5	4	1	155
4	2	1	1	2	0	0	0	0	51	5	12	2	11	2	3	3	95
5	2	0	1	0	0	0	0	0	27	1	5	3	34	2	3	1	79
6	3	1	0	0	0	3	0	0	47	12	33	6	13	15	11	1	145
7	7	9	0	1	1	7	0	0	26	0	15	14	17	28	12	9	146
8	0	5	1	4	0	2	0	3	13	4	5	5	32	15	2	11	102
9	3	2	0	4	0	0	0	0	27	1	5	6	15	10	2	14	89
10	1	1	0	0	2	1	0	0	20	1	8	5	6	9	2	0	56
11	2	0	1	1	1	0	0	0	27	2	9	4	8	1	3	13	72
12	1	0	1	0	0	1	0	2	16	1	18	11	12	1	4	4	72
Total	31	39	9	45	16	26	6	6	535	101	242	106	279	148	88	131	1808
	70		54		42		12		636		348		427		219		
	124				54				984				646				
	178								1630								

[a] Each entry is the total count on 25 traps for the day. A = *Cosmopolites sordidus*. B = *Metamasius sericeus*. Surface recut after 7 days on June 5.

almost entirely of Bout Rond plants. Comparable groups of traps on the two farms were separated by a distance of approximately 100 yards.

Weevils were collected and counted each morning for a period of 2 weeks. At the end of the first week the dried adjacent faces of the traps were pared to determine the effect of this treatment on the number of weevils attracted. Daily totals for the 25 traps of each kind in all locations are tabulated in table 2. Preliminary trapping trials showed that the heaviest catches of weevils were obtained in traps placed in the shade and in those that had been kept moist. Traps left in the open dried out quickly, and attracted relatively few weevils. Similarly, traps made by placing the cut surfaces of two pieces of stem or rhizome face to face were more effective than those consisting of single pieces laid on the ground.

From table 2 it is apparent that freshly cut traps attracted more weevils than those that had been cut for some time, the number of beetles caught being approximately proportional to the length of time since the surfaces were cut. Shaving off the dried surfaces of old traps resulted in an increase in the number of weevils caught as demonstrated by the increased number trapped after the surfaces were recut on June 5. Since the maximum number of weevils were trapped within the first 48 hours, recutting of trap surfaces every 2 days is recommended for work of this kind. The effectiveness of chlordane in reducing the weevil population is obvious from the data presented in table 2. These data also indicate that chlordane is more effective in reducing populations of *C. sordidus* than of *M. sericeus*.

The application of the Chi-square test to the data in table 2 shows that the preference of *C. sordidus* for Gros Michel rhizome tissue over Bout Rond rhizome tissue is highly significant. Similarly that the preference of *C. sordidus* for rhizome tissue rather than stem tissue is highly significant. In the case of *M. sericeus* no preference for rhizome rather than pseudostem or for Gros Michel rather than Bout Rond was shown.

Correlation Between Head Rot and Weevil Attack.—In order to determine whether the amount of head rot is correlated with the weevil population in the Gros Michel plants, a further investigation was carried out on the same farms. On each farm, 10 Gros Michel mats were picked at random from each of five, 2-hectare sections. Adjoining sections on the two farms were not used in order to avoid border effects from the application of chlordane. The 100 mats were dug and examined for head rot. Two rhizome traps were cut from each mat, the sections being carefully examined for the presence of head rot. One trap was laid at either side of the road at the base of the nearest banana plant so that the traps would sample as nearly as possible the true weevil population of the farm. Weevil counts were made every day for 10 days, the surface of the traps being recut every second day to insure the greatest possible catch. The daily totals are shown in table 3.

The sample of Gros Michel plants dug on the two farms showed an equal amount of head rot in each, i.e., nine affected mats or 18 per cent. This percentage is small when compared with that on a severly infected farm. It indicates, however, that although the application of chlordane had reduced the beetle population, it had had no appreciable effect on the reduction of the number of head rot infected plants on the farm.

The advantage of using only rhizome traps and of re-

Table 3.—Weevil counts on rhizome traps 10 days consecutively.[a]

	CALPULES (CHLORDANE)										ROSARIO (NO CHLORDANE)										
SECTION[b]	I-23		I-24		I-25		I-26		I-28		I-31		I-32		I-33		I-34		I-35		DAILY TOTAL
Day	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	
1	2	14	2	3	1	7	0	5	0	15	34	26	80	123	81	147	66	106	57	112	881
2	4	23	3	0	2	8	2	3	0	11	39	8	70	38	112	44	67	40	69	44	587
3	3	4	1	6	0	18	0	4	1	18	49	5	72	31	98	56	123	79	71	37	676
4	4	26	0	6	2	10	0	7	0	12	41	3	48	25	81	72	80	132	62	96	707
5	3	25	0	4	0	6	0	2	0	19	28	1	43	39	70	61	52	77	54	43	527
6	4	23	1	3	0	27	0	0	0	17	19	4	49	16	74	23	78	19	69	24	450
7	9	9	1	1	0	2	0	0	1	8	23	2	95	18	161	72	99	57	64	15	637
8	9	29	1	2	2	18	3	7	2	8	34	0	79	25	81	53	88	42	58	5	546
9	14	37	0	5	3	20	0	4	2	11	51	8	55	32	85	60	54	9	23	7	480
10	41	68	1	5	7	22	0	2	1	24	53	7	60	3	80	10	94	32	50	5	565
Totals	93	258	10	35	17	138	5	34	7	143	371	64	651	350	923	598	801	593	577	388	
	351		45		155		39		150		435		1001		1521		1394		965		
	740										5316										6056

[a] Surface recut every second day.
A—*Cosmopolites sordidus.*
B—*Metamasius sericeus.*
[b] 10 rhizome traps set out in each 10 hectare section.

cutting at 2-day intervals is reflected in the total number of weevils collected during the 10-day period as compared with the earlier 14-day period. The weevil counts set out in table 3 emphasize the marked difference in the weevil populations of the two farms. These totals rather than those in table 2 must be considered as indicative of comparative farm populations and therefore of the effectivity of chlordane, since the figures in table 3 were obtained from more effective traps and sampled a larger area of each farm. The fact that the reduction in weevil population must be due principally to the action of chlordane is emphasized when totals from sections on the two farms containing an approximately equal number of Gros Michel plants are compared. Section I-31 in Rosario with approximately 20% Gros Michel yielded 371 *C. sordidus* while I-25 in Calpules with an estimated 30% Gros Michel yielded only 17 of these weevils, thus verifying the part played by chlordane in population reduction. A similar situation existed elsewhere on the two farms.

The fact that *C. sordidus* is more suceptible to control by the application of chlordane than *M. sericeus* is clearly indicated from the data tabulated in tables 2 and 3. In each of the untreated areas the population of *C. sordidus* was greater than that of *M. sericeus*. In the treated area, on the other hand, the population of *M. sericeus* was greater. It is suggested that this was due to the fact that *M. sericeus* unlike *C. sordidus* is able to fly and can avoid material around the base of the banana mats treated with chlordane; also to the fact that *M. sericeus* has less specialized tastes (Table 2) and is satisfied to feed on decomposing banana trash that accumulates between spray applications.

WEEVILS IN NEW PLANTATIONS.—During the early part of the head rot investigations, the constant association of the banana weevil, *C. sordidus*, with advanced stages of head rot made it seem likely that the weevil was in some way associated with or responsible for the disease. However, when a young plantation reached a suitable age for examination, digging showed that head rot was present in rhizomes showing no sign of weevil attack. The absence of weevils was due to the care with which the seed had been handled. Nevertheless, due to the rapid propagation of the weevil, 95 to 100 per cent of all mats were infested by the time the first crop was cut a year later. In a few cases ants working over the decayed tissue left it in such a state that it had the superficial appearance of weevil attack.

Weddel (1945) recommended the paring of banana "seed" to a depth of at least 1/8 inch in order to remove any *Cosmopolites* eggs and to expose any larval tunnels already present. The eggs cannot be located with the naked eye but their presence in seed may be responsible for the introduction of the weevil into new areas. The disadvantage of this method lies in the damage that is done to all the small buds on the rhizome by the paring. Decay of the pared seed piece may occur before new buds can develop. A compromise can be reached by paring only the lower half of the rhizome where relatively few of the eyes develop. Spraying the seed with 1:1000 solution of chlordane after it is dug also reduces the possibility of further egg laying by adults.

SUMMARY.—*Cosmopolites sordidus* attacks rhizomes of banana independently of the head rot organism, and carries out its activities wherever possible on healthy tissue. As in abaca, it is responsible for losses due to tip-over only to the extent that its tunnels reduce the structural strength of the plant. In the course of experimental studies, the weevils which fed and oviposited on healthy rhizome tissue were never found to induce decay in the substratum. Chlordane, diluted 3:2000, applied at the rate of 200 gallons per hectare at monthly intervals greatly reduced weevil populations. The chlordane apparently produced no harmful effect on the banana plants. Rhizome traps were found more effective than those cut from pseudostems. Fresh surfaces cut on the rhizome traps every 2 days increased the catch appreciably. *C. sordidus* shows a feeding preference for Gros Michel rhizomes over rhizomes of the Bout Rond variety. It is of commercial interest that the variety Bout Rond, which is highly resistant to Panama disease and to head rot, is less likely to be severely damaged by the banana weevil.

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Selection for DDT Resistance in Inbred, Laboratory, and Wild Stocks of *Drosophila melanogaster*[1]

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The current literature is becoming filled with reports on the rather rapid development of resistance to various insecticides by many insect species (reviews by Babers 1949, Babers & Pratt 1951, and Metcalf 1955) to the point where it appears that almost any species can become resistant to almost any insecticide. The increased resistance of exposed insects has been attributed to various causes. One major theory is that the process of natural selection is at work on the available genetic variability, the more resistant members of each generation surviving to reproduce. Another theory is that the increased resistance is due to a direct response by the insect to the insecticide. Thus, in one case, a change in the hereditary characteristics of the population and hence an evolutionary change is assumed to be responsible for the adaptation to insecticides; in the other, increased resistance is thought to be due to the ability of each insect to adapt directly to the presence of the insecticide by suitable changes in its physiology. The issue has been further complicated by apparently conflicting reports as to the degree of resistance retained after resistant stocks have been taken off the insecticide for several generations.

This paper reports the results of studies of the development of DDT resistance in populations of *Drosophila melanogaster*. They were undertaken with the premise that the increase in resistance is due to natural selection and that it should thus be possible to study small scale evolution in the laboratory.

The first step was to make some sort of test of the initial premise. If an increase in resistance to insecticides is due to natural selection, the frequency of genes conferring higher resistance should increase in the population. Under this assumption, a prerequisite for any increase in resistance is that the initial population should be genetically heterogeneous or heterozygous at those loci involved in resistance. If the initial population is genetically uniform, no resistance should develop. On the other hand, if increased resistance is due to some sort of direct adaptation, then the genetic make-up of the initial population should not matter. Under this hypothesis, resistance should appear with equal ease in homozygous and heterozygous populations. It is therefore significant that populations derived from two inbred stocks of Drosophila, exposed to DDT over a period of 30 months, both failed to become DDT resistant, but that more heterozygous stocks, similarly exposed, have developed varying degrees of resistance.

METHODS.—The populations were maintained in population units devised by Reed & Reed (1948) and Ludwin (1951). Each unit consists of two ½-pint milk bottles united by a 3-inch piece of automobile radiator hose (2 inch diameter). For ventilation and sampling, a ¾-inch hole was cut into the hose and tightly plugged with cotton. A standard Drosophila food medium consisting of corn meal, corn syrup, agar, brewer's yeast, and Moldex was allowed to harden in a slant while the bottles lay on their sides. The bottles were replaced alternately so that the population could be maintained indefinitely with little disturbance. To expose a population to DDT, a 1″x3″ strip of filter paper impregnated with technical grade DDT (M.P. 92° C.) was placed on the surface of the food. (All of the DDT used in these experiments came from one sample supplied by McLaughlin, Gormley, King Co. of Minneapolis). In this way, both larvae and adults were exposed to the insecticide. The concentrations were varied from 0.1 to 10 mg. so that a large percentage, generally more than 50% and more often from 75 to more than 90% of the adult flies was killed. At times the DDT strip was not added to the new food bottle so that the population had a chance to increase in numbers. The control populations were maintained in the same fashion except that no DDT impregnated strips were added. All of the populations were kept in a constantly lighted room at 21±1° C. and 50% relative humidity throughout the experiments.

The method of testing has been modified during the course of the experiments. Various authors (Crow 1954, King 1955) have mentioned the difficulties in testing for resistance, and the search has been for a test with good reproducibility. The initial tests involved vials lined with DDT impregnated paper similar to those described by Crow (1954). Next a test devised by Bartlett (1951) was used, and the final method developed is a modification of Bartlett's testing procedure.

The flies tested were the offspring of adults taken from the population bottles. These adults were transferred to ½-pint culture bottles to breed and lay their eggs, 10 males and 10 females to each bottle. The progeny were sexed, and the females were placed on fresh food in a ½-pint bottle for 24 hours before testing. Because of the difference in resistance between the sexes (e.g. Bochnig 1954, Crow 1954), only females were tested.

The tests were conducted in petri dishes into which had been pipetted a ml. of acetone with the desired amount of DDT. The females were etherized and placed in the petri dishes, and after 6 hours, the number of flies still

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able to stand was scored. In the 24-hour tests, the acetone solution was pipetted on to a filter paper covering the bottom of the petri dish, but for the 6-hour tests the solution was pipetted directly on to the glass bottom of the dish. This difference in surface made considerable difference in the ED_{50}, which was lower on the glass surface.

The method of scoring puts together both dead flies and those only knocked down, but it is a criterion widely used and easy to score (Finney 1952). Anesthesia prior to exposure has been shown by Proverbs & Morrison (1947) to have no effect on mortality. It should be noted that the method of exposure and the method of testing for resistance were different and that the flies tested had never been exposed to DDT.

To minimize environmental variables, the DDT-exposed stock and its unexposed control were always grown and tested in this fashion simultaneously. Up to a maximum of 50 females per plate were tested. When tests were repeated on successive days, the exposed stock was tested on the plates used for its control the previous day and *vice versa*.

Crow (1954) has commented on some aspects of testing in determining the relative degree of resistance in different strains. He found that a strain which tested six times as high as its control in a 6-hour test, tested 2000 times as resistant in a 24-hour test. No such striking differences were found between the various tests used in these experiments, but the procedures used were different. However, the 6-hour test was ultimately settled upon in preference to the 24-hour period because it seemed less likely that other differences (e.g., the ability to withstand lack of moisture) would obscure the test results in the shorter period.

The statistical analysis of the data was made following the approximate methods outlined by Finney (1952). Finney points out that the standard errors obtained are meaningful only on the logarithmic scale, and for this reason the log ED_{50} and its standard error are reported in the tables. However, the comparisons of the relative resistance between the exposed populations and their controls are more understandable when given as the ratio, exposed ED_{50}/control ED_{50}. Tests of the adequacy of the equation showed significant discrepancies from the probit regression line in some cases, but since there was no apparent trend in the type of discrepancies, the method was considered adequate if too great reliance is not placed on the precision of the estimates.

RESULTS.—*Inbred Stocks.*—The inbred stocks used were a strain of *Drosophila melanogaster* known as Oregon R (OR_{25}) which had been brother-sister inbred for 25 generations, and another strain, Lausanne Special (LS_{23}) which had been brother-sister mated for 23 generations. Although these strains were highly inbred, the results of Gowen *et al.* (1946) indicate that inbred lines obtained by brother-sister mating can not be considered completely isogenic. Nevertheless, compared to the highly heterozygous wild populations of Drosophila (Dobzhansky 1951), these inbred lines must be relatively homozygous.

The exposure of the two inbred stocks, LS_{23} and OR_{25}, to DDT in the population bottles lasted for 30 months, from May 1951 to October 1953. This period would correspond to a maximum of 60 generations at the temperature used, or more probably about 40 generations. During this period the stocks were tested about every 6 months, but no increase in resistance to the exposed over the controls was found.

Table 1.—Tests of DDT resistance in inbred lines and their hybrids (Aug. 1952—24-hr. test).

	Concentration (Mg.)	Control		Exposed	
		Number	Per Cent Down	Number	Per Cent Down
Oregon R_{25}	0.1	25	0.0	40	0.0
	0.25	237	3.7	198	6.8
	0.5	244	31.1	198	19.6
	1.0	160	65.5	198	60.6
	2.5	161	80.5	113	84.0
	5.0	194	97.4	168	98.8
		log ED_{50} = 3.01 ± .02		log ED_{50} = 2.96 ± .02	
Lausanne Special$_{23}$	0.1	20	0.0	30	0.0
	0.25	206	29.2	126	12.6
	0.5	206	55.3	126	43.6
	1.0	206	81.0	126	95.2
	2.5	95	100.0	62	100.0
	5.0	206	100.0	126	99.2
		log ED_{50} = 2.69 ± .01		log ED_{50} = 2.68 ± .02	
		Population 1		*Population 2*	
OR_{25} females × LS_{23} males	0.25	227	20.2	169	24.2
	.5	227	49.7	179	65.3
	1.0	227	71.8	179	91.6
	2.5	176	98.2	179	92.1
	5.0	227	92.5	179	99.4
		log ED_{50} = 2.76 ± .02		log ED_{50} = 2.62 ± .02	
		Population 1		*Population 2*	
LS_{23} females × OR_{25} males	0.25	232	12.9	176	8.5
	.5	239	46.4	176	56.8
	1.0	239	81.5	176	88.0
	2.5	156	98.7	126	99.2
	5.0	239	98.3	176	98.8
		log ED_{50} = 2.77 ± .02		log ED_{50} = 2.73 ± .02	

Hybrids were formed by reciprocal crosses between OR_{25} and LS_{23}, and two populations of each reciprocal cross were exposed to selection. By the end of 11 months, no increase in resistance had been detected in these hybrid stocks, and selection was discontinued. To illustrate the results of tests for resistance in these inbred stocks and their hybrids, the tests conducted in August 1952 are shown in table 1. It should be noted that the OR_{25} populations, both exposed and control, are about 1.9 times more resistant than the LS_{23} stocks. Furthermore, the hybrids appear to have a resistance comparable to the LS inbred.

Laboratory Stocks.—Five wild type stocks originally collected in widely separated areas of the world were obtained from Cold Spring Harbor and exposed to DDT. These stocks are known as Crimea; Tuscaloosa, Alabama; Kyoto, Japan; Salta, Argentina; and Swedish b-6. These stocks had been maintained in laboratories for some time and hence were presumably somewhat inbred since, in the maintenance of laboratory stocks, rather small numbers of parents are usually used. After 5 months of exposure, tests indicated that all of these stocks had a low level of resistance, which was not being appreciably raised by selection. As above, the lines showed differences in their degree of resistance. Kyoto and Swedish b-6 showed some indication that the level of resistance was somewhat higher in the exposed populations, but not greatly so. The Crimea exposed stock was so susceptible to DDT that it was not feasible to remove the 80 flies from the population necessary to start cultures for testing. Therefore, these five exposed populations were combined as

Table 2.—Tests of DDT resistance in M-1, derived from 5 laboratory stocks.

	Concentration (Mg.)	Control		Exposed	
		Number	Per Cent Down	Number	Per Cent Down
(Dec. 1953—6-hr. test)	0.01	160	0.0	95	1.0
	.1	160	8.1	95	9.5
	1.0	160	61.9	101	58.4
	10.0	150	90.7	85	84.7
		$\log ED_{50} = 2.97 \pm .05$		$\log ED_{50} = 2.98 \pm .07$	
(Aug. 1954—6-hr. test)	0.01	110	2.7	145	1.4
	.1	114	14.0	145	9.6
	1.0	104	54.8	150	65.3
	10.0	84	94.0	145	100.0
		$\log ED_{50} = 2.78 \pm .06$		$\log ED_{50} = 2.73 \pm .05$	

follows: 10 Swedish b-6 males were crossed to 10 Kyoto females; 10 Kyoto males were crossed to 10 Salta females; 10 Salta males were crossed to 10 Tuscaloosa females; 10 Tuscaloosa males were crossed to 10 Crimea females; 10 Crimea males were crossed to 10 Swedish b-6 females. Then 10 males and 10 females from the F_1 of each of these crosses, 100 flies in all, were used to start a new population, called M-1, which was exposed to DDT, another 100 flies from these crosses being used to start the control.

Selection was continued in this combined line for over 2 years, but no increase in resistance appeared during this period. In table 2, the results of two 6-hour tests are shown, which indicate that the level of resistance has apparently remained fairly constant.

Laboratory stocks of Lausanne Special (LS) and Oregon R (OR) which were not inbred just prior to use were also exposed to DDT. This LS stock was descended from a line which had been brother-sister mated for 30 generations by S. C. Reed, ending in 1947, but the OR strain is not known to have undergone such rigorous inbreeding, at least since 1946. The tests (Table 3) show that there has been no increase in resistance in the LS stock over its control despite exposure for more than 2 years.

The exposure of the OR laboratory stock to DDT did, however, result in increased resistance to DDT (Table 4). The increased resistance appeared rather soon after selection began and persisted without further increase for some time. Thus, two populations descended from OR differed in their response to exposure to DDT; the inbred line failed to become more resistant, but the non-inbred stock did. A rather unexpected result was later obtained when the resistant stock, despite its continued exposure to DDT, declined in resistance. A similar change has occurred in two of the wild stocks (see below).

Table 3.—Tests of resistance in Lausanne Special.

	Concentration (Mg.)	Control		Exposed	
		Number	Per Cent Down	Number	Per Cent Down
(Aug. 1952—24-hr. test)	0.10	45	6.6	50	0.0
	.25	223	17.9	233	12.8
	.50	248	50.0	253	40.7
	1.0	248	67.3	253	64.4
	5.0	248	92.7	253	98.0
		$\log ED_{50} = 2.97 \pm .02$		$\log ED_{50} = 2.98 \pm .02$	
(Sept. 1953—6-hr. test)	0.01	53	3.8	190	4.7
	.1	53	73.6	192	82.8
	1.0	53	100.0	192	99.5
		$\log ED_{50} = 1.84 \pm .07$		$\log ED_{50} = 1.82 \pm .04$	

Table 4.—Tests of resistance in Oregon R.

	Concentration (Mg.)	Control		Exposed	
		Number	Per Cent Down	Number	Per Cent Down
(July 1952—24-hr. test)	0.25	195	13.3	236	2.9
	.5	195	63.5	236	12.2
	1.0	195	75.8	236	21.6
	5.0	195	97.9	236	78.3
		$\log ED_{50} = 2.73 \pm .02$		$\log ED_{50} = 3.38 \pm .03$	
		$\frac{ED_{50}\ Exposed}{ED_{50}\ Control} = 4.4$			
(Mar. 1953—24-hr. test)	0.05	92	34.8	87	10.3
	.10	100	39.0	100	11.0
	.25	100	96.0	100	37.0
	.50	100	100.0	100	59.0
		$\log ED_{50} = 1.95 \pm .03$		$\log ED_{50} = 2.58 \pm .04$	
		$\frac{ED_{50}\ Exposed}{ED_{50}\ Control} = 4.3$			
(Nov. 1953—6-hr. test)	0.01	100	0.0	77	0.0
	.1	100	36.0	77	2.6
	1.0	100	99.0	77	67.5
	10.0	99	100.0	77	96.1
		$\log ED_{50} = 2.15 \pm .05$		$\log ED_{50} = 2.90 \pm .07$	
		$\frac{ED_{50}\ Exposed}{ED_{50}\ Control} = 5.6$			
(Feb. 1955—6-hr. test)	0.01	250	0.4	218	0.9
	.1	250	9.6	225	9.3
	1.0	247	85.4	220	70.4
	10.0	249	90.0	225	74.7
		$\log ED_{50} = 2.82 \pm .04$		$\log ED_{50} = 3.10 \pm .05$	
		$\frac{ED_{50}\ Exposed}{ED_{50}\ Control} = 2.0$			

At the same time that rigorous selection was being carried on in the OR stock, less rigorous selection was practiced in another population of this same stock by exposing it to a concentration of DDT only one-tenth as great. With selection pressure thus lowered, no increase in resistance was detected in this exposed stock as compared to the control (Table 5).

Wild Stocks.—A number of stocks which had been collected from local wild populations in the Twin Cities were also exposed to DDT. These populations were not started from single females, as is customary in starting laboratory strains from wild flies, but were started with from 10 to 50 flies collected at the same time and place in an attempt to obtain a fair amount of the genetic variability from the sampled populations. Very little is known of the field history of these flies or of most species of Drosophila. However, it is not likely that they survive the winter out-of-doors in Minnesota. Nevertheless, by autumn the population of *Drosophila melanogaster* has grown to such size that this species far outnumbers all others taken in the traps, which were baited with banana.

These populations are known as 2, 17, 91, 731, RAK, and IT. After selection had gone on for at least 6 months in these stocks, all showed increased DDT resistance when compared to their controls except 731. In this case, however, the control had a rather high level of resistance. After at least 6 months' exposure, the following exposed stocks, OR, 2, 17, RAK, and IT were made up into a second combined stock, M-2. The same method used to

Table 5.—Test of DDT resistance in the Oregon R population[a] under weak selection pressure.

	Concentration (Mg.)	Control Number	Control Per Cent Down	Exposed Number	Exposed Per Cent Down
July 1952—24-hr. test)	0.25	195	13.3	178	24.7
	.5	195	63.5	178	61.7
	1.0	195	75.8	178	73.5
	5.0	195	97.9	178	99.4
		$\log ED_{50} = 2.73 \pm .02$		$\log ED_{50} = 2.66 \pm .02$	

[a] Exposed to one-tenth concentration of DDT used on population in table 4.

form M-1 was followed, with the M-2 control coming from the exposed lines also. The resistance of the stocks used to form M-2 compared to their controls is shown in table 6. It should be noted that the relatively high resistance of the IT strain is primarily due to the low absolute level of resistance of its control. The M-2 stock was then exposed to selection by DDT in March 1953. The exposed stock has again developed increased resistance compared with its control (Table 7). The M-2 exposed population was subdivided into three populations in May 1954.

It was pointed out previously that the OR_{25} inbred was roughly twice as resistant as the LS_{23} inbred strain. That different strains have different levels of resistance can be further illustrated from the data in the wild stocks shown in table 8. Although comparisons of the levels of resistance in different stocks on an absolute basis are not very reliable because of the environmental variables, which were minimized in testing control and exposed lines of the same stock, nevertheless comparisons based on tests run over the same period have some general validity. The data in table 8 are taken from tests run during July and August, 1954, and therefore should be roughly comparable. It can readily be seen that some of the controls differ markedly from each other in resistance, and that the exposed stocks also differ in resistance from each other as well as from their controls.

If the assumption is correct that inbreeding had produced homogeneity within the OR_{25} and LS_{23} strains as compared with the more heterozygous wild stocks, it should be possible to detect this difference from the probit analysis. It is interesting, therefore, to find that by examination of the many probit regression lines, it was found that the slope of the lines for the inbreds was generally much steeper than for the wild stocks. This result would seem to indicate the greater uniformity in the response of the inbreds to the test. A further generalization is that in the stocks in which resistance appeared, the slope of their probit regression lines was less than the slope of their respective controls. A possible interpretation of this finding is that segregation and recombination are still occurring in the resistant lines to produce susceptible flies. Only if homozygosity for the genes for resistance were approached or achieved would the slope again become steeper.

Table 7.—Tests of DDT resistance in M-2 populations.

	Concentration (Mg.)	Control Number	Control Per Cent Down	Exposed Number	Exposed Per Cent Down
(Sept. 1953—6-hr. test)	0.01	145	4.1	125	4.0
	.1	145	20.7	125	12.0
	1.0	145	56.5	125	42.4
	10.0	145	67.6	125	50.4
		$\log ED_{50} = 3.10 \pm .08$		$\log ED_{50} = 3.85 \pm .11$	
		$\frac{ED_{50}\text{ Exposed}}{ED_{50}\text{ Control}} = 5.6$			
(May 1954—6-hr. test)	0.01	186	4.8	75	2.7
	.1	180	35.0	75	9.3
	1.0	180	90.5	75	70.7
	10.0	127	99.2	52	90.4
		$\log ED_{50} = 2.17 \pm .05$		$\log ED_{50} = 2.75 \pm .08$	
		$\frac{ED_{50}\text{ Exposed}}{ED_{50}\text{ Control}} = 3.8$			
				Exposed (a)	
(Aug. 1954—6-hr. test)	0.01	88	1.1	127	7.9
	.1	88	10.2	130	9.2
	1.0	88	76.1	129	38.0
	10.0	83	98.8	119	98.0
		$\log ED_{50} = 2.58 \pm .06$		$\log ED_{50} = 2.75 \pm .07$	
		$\frac{ED_{50}\text{ Exposed}}{ED_{50}\text{ Control}} = 1.5$			
		Exposed (b)		*Exposed (c)*	
(Aug. 1954—6-hr. test)	0.01	170	4.1	158	1.3
	.1	175	8.0	158	5.7
	1.0	175	44.0	158	57.0
	10.0	175	67.4	155	71.0
		$\log ED_{50} = 3.35 \pm .07$		$\log ED_{50} = 3.26 \pm .06$	
		$\frac{ED_{50}\text{ Exposed}}{ED_{50}\text{ Control}} = 5.9$		$\frac{ED_{50}\text{ Exposed}}{ED_{50}\text{ Control}} = 4.8$	

The way in which resistance developed in the various populations should be noted. In most cases, the response to selection occurred in the first months after selection had begun, and then the resistance remained at the new level without change for some time (e.g., OR remained at about five times its control from July 1952 to at least November 1953; RAK at about three times its control from March 1953 to March 1954; M-2 at about five times its control from September 1953 to September 1954 except in M-2a). However, population 731, with a high

Table 6.—Resistance of exposed stocks used to form M-2 compared with their controls.

Stock	Exposed ED_{50} / Control ED_{50}
2	1.5[a]
17	3.6[a]
RAK	3.0[a]
IT	11.5[a]
OR	4.3[a]

[a] Exposed stock significantly more resistant ($p<.01$).

Table 8.—Comparison of resistance among control and exposed stocks. (July–Aug. 1954—6-hr. tests)

Stock	Control ED_{50} (μg.)	ED_{50} Control / ED_{50} IT Control	Exposed ED_{50} (μg.)	ED_{50} Exposed / ED_{50} Control
IT	210	1.0	1780	8.5
91	230	1.1	1580	6.9
RAK	245	1.2	490	1.6
M-2	380	1.8	(a) 560	1.5
			(b) 2240	5.9
			(c) 1820	4.8
731	760	3.6	1780	2.3

level of resistance at the outset which was retained by the control, showed no major increase in resistance for more than 18 months before finally showing an increase to 6.2 times its control on the most recent tests. At one time during this period the resistance of the exposed stock fell significantly below that of the control (Table 9).

The wild stocks in which an initial increase in resistance has been followed by a decline despite continued selection were RAK and M-2a. In these stocks and in OR, the drop in resistance was indicated not only by the tests (in OR the drop was from a high of 5.6 times the control to two times the control; in RAK from 3.1 down to 1.4 times the control; and in M-2a from 5.6 to 1.5 times the control), but even more strikingly by the exposed populations themselves. In all three, the exposed populations had to be watched carefully, the amount of DDT to which they had been exposed and had previously tolerated to be reduced and at times discontinued altogether to permit the populations to survive and to build up their numbers.

The finding reported previously with respect to the OR stock, that exposure to lower concentrations of DDT was not as effective in producing resistant populations as more rigorous selection pressure by higher concentrations was also made in population 91 and in 731 (Table 9). In these cases the concentration for the lower dosage was half as great as that used for the more rigorous selection.

DISCUSSION.—The results of these and many other studies of resistance to insecticides can most easily be interpreted in terms of the action of natural selection upon the available genetic variability of a breeding population.

The inbred populations, OR_{25} and LS_{23}, failed to become more resistant because of their lack of variability. Favorable mutations apparently did not accumulate to any extent during the 30 months of exposure nor did the DDT appear to have induced mutations which confer greater resistance. More critical tests by Pielow (1952) revealed no mutagenic effects when males exposed to DDT as larvae were tested. It is interesting to note that the single laboratory stock of *D. melanogaster* tested by King (1954), like six of the seven laboratory stocks tested in these experiments, did not become resistant. It seems probable that the reason that these laboratory strains failed to develop resistance when exposed to DDT, is that all laboratory stocks tend to become somewhat inbred and hence to lose some of their genetic variability.

Table 9.—Effect of concentration of DDT on level of resistance.

		Low Dosage[a]	High Dosage
		ED_{50} Exposed	ED_{50} Exposed
Stock	Test	ED_{50} Control	ED_{50} Control
91	July 1954	1.0	6.9[b]
	Sept. 1954	3.2[b]	13.2[b]
	Mar. 1955	0.9	9.6[b]
731	Apr. 1954	1.1	0.2[b]
	July 1954	1.7	2.3[b]
	Jan. 1955	1.6	6.2[b]

[a] Low dosage kept at one-half concentration of high dosage.
[b] Exposed stock significantly different from control ($p<.01$).

In the case of the M-1 hybrid and the hybrids between OR_{25} and LS_{23}, no increase in resistance over the controls was detected. There are at least two alternative explanations for these results. Either the crosses produced little increase in variability and hence nothing new for selection to act upon, or else the variability was such that the new combinations of genes conferred no greater resistance than the old. Since the flies used to form the hybrid populations were of diverse origin and hence very unlikely to be genetically identical, the latter explanation seems more probable.

The most marked increases in resistance were obtained in the stocks which had not been inbred. This resistance is presumbably due to the selection of favorable genes or gene combinations since it appeared in heterozygous but not in inbred populations. It is unlikely that the increased resistance was due to heterosis because the controls would have been expected to show greater heterosis than the exposed population, in which the high mortality would tend to reduce the effective population size, the heterozygosity, and the heterosis.

In the stocks becoming resistant, the development of resistance was directly related to the strength of the selection pressure, a finding similar to that of Patton & Whittemore (1949) and Pimental *et al.* (1953). King (1954), however, reported a low selection intensity to be as effective as a high one. In general, it would seem that the higher selection pressures would be more effective in causing resistant strains to evolve, unless the pressure is so great that considerable inbreeding and loss of variability occur.

Tests of the mode of inheritance of DDT resistance in these stocks have not been completed, but multiple factors appear to be involved. Various authors have reported that increased resistance is due to multiple factors (Bochnig 1954, Crow 1954, and King 1954, in Drosophila; Bruce & Decker 1950, in house flies). Drosophila Information Service 28 contained reports, which presumably soon will be published, that increased resistance to DDT was controlled by a dominant gene on the second chromosome. In the house fly, Harrison (1953) has data which suggest that a single locus is involved in knockdown and multiple factors in kill. These differences between different populations of the same species are to be expected if resistance is the result of natural selection. If no genes conferring resistance are present in the population, no increase can occur in response to selection. If such genes are present, they may in one population be polygenes, in another a single dominant, in another, recessive, or they may be a combination of any of these. Natural selection will act, to produce resistance, along any path that is open; the genes, whatever their nature and effects, which increase chances of survival in the presence of DDT will tend to increase in frequency. Hence, different populations of the same species may become resistant by different genetic mechanisms.

In at least two cases (Cochran *et al.* 1952, Johnston *et al.* 1954), cytoplasmic inheritance has been invoked to explain the increase in resistance. However, since the differences between reciprocal crosses were found by Cochran *et al.* only in the F_1 and not in subsequent genera-

tions, their results may be due to a maternal effect, the cytoplasm of the eggs from a resistant mother having been influenced by the chromosomes which were present in the eggs prior to the meiotic divisions and fertilization. The report of Johnston *et al.* with the house fly is more difficult to evaluate. They postulate that their results are due to cytoplasmic resistance particles under the control of one or more nuclear genes, with DDT itself having a stimulating effect on the reproduction of the cytoplasmic particles. The greatest difficulty with this theory is that there were no differences in the F_1's from reciprocal crosses, which would be expected under such a theory.

Three stocks, OR, RAK, and M-2a, which at first responded to selection and became more resistant than the controls, later declined in resistance despite continued selection. This result was most unexpected and unusual. However, in an initially heterozygous population, long continued rigorous selection has two effects. It favors those genes and combinations of genes which interact to confer greater DDT resistance. Also, when selection pressure is as strong as it was in the population bottles, the effective size of the breeding population is reduced to the point where a considerable amount of inbreeding must occur. The population bottles can produce, at a maximum, 600 to 700 flies, but on occasion as few as 10 or 12 surviving adult flies were observed in the exposed populations. Under these circumstances, some inbreeding is inevitable. The effect of the resulting increased homozygosity may have two different aspects. In the first place, since the initial populations were heterozygous, there were undoubtedly many deleterious recessive genes carried in the heterozygous condition. With continued inbreeding, these deleterious genes will be expressed more frequently in the homozygous condition, or possibly even become fixed in the population, with the result that the general viability of these lines will decrease, and hence their ability to tolerate DDT. Furthermore, since it has been reported that relatively few genes may be responsible for increased resistance, it should not be surprising that, when rigorous selection reduced the population size to the point where considerable inbreeding occurred, the genes favorable to resistance might easily be lost from the population. If so, this represents a case of random genetic drift, in which, despite continued strong selection pressure, the less well adapted types have become established, a theoretical possibility which has been explored by Sewall Wright (1948).

When resistant lines have been taken off DDT, some authors have found no reversion from resistance to susceptibility after many months (Crow 1954, with Drosophila; Bruce & Decker 1951, with house flies). Others have reported a rather rapid decrease (Bochnig 1954, with Drosophila; Pimental *et al.* 1953, with house flies). If one or just a few genes are involved in resistance and the population has become homozygous for these genes, it will then remain resistant. However, if it has remained heterozygous, the chances are that at least some degree of resistance will be lost, selection tending to favor other genes conferring lower resistance in the absence of DDT, as Crow (1952) has pointed out. The rate of reversion will depend on the frequencies and relative adaptive values of the genes involved. The slope of the probit regression line should have predictive value in indicating whether or not a given stock will remain resistant.

There have also been differences between the reports on comparisons of resistant and susceptible strains with respect to other morphological and physiological traits. Some authors have found no other differences between resistant and suceptible lines while others have found several (March & Lewallen 1950, Babers *et al.* 1953, Pimental *et al.* 1951, Grayson 1954, Varzandeh *et al.* 1954). Since each population confronted by the selection pressure exerted by DDT is genetically unique and different from all others, it is clear that not only the genetic mechanisms by which greater resistance is achieved may differ, but that hereditary differences affecting other traits may appear as well. For, once the exposed population is isolated from the control population, they are both subject not only to differences in their exposure to DDT, but to the possible effects of differences in other selection pressures, in mutation pressure, and in population size. Migration alone is excluded in experimental populations, but may be of great importance in natural populations. Therefore, the other traits in which resistant and susceptible strains differ may or may not be related to the greater resistance. Only experimental tests can determine this point.

King (1955) has recently reported on the results of crosses between two independently developed resistant lines, descended from the same wild stock. He found that the F_1 had the same resistance as the parent lines, but that the F_2 had a significantly lower resistance and a mortality distribution of greater variance than the parents. He suggests therefore that the genetic mechanisms controlling resistance in these two lines must be different. The results of the crosses are interpreted in terms of the "integration of the gene pool" of each population, the concept being that the genes within the same population are coadapted to each other (for further discussion and references, see King 1955). Since the number of flies used by King in making the crosses was not reported, an alternative possibility remains that the decrease in resistance in the F_2 was due to the segregation of deleterious recessive genes. However, whether or not coadaptation ultimately plays a role in increased resistance in this case, it does seem likely that the type of mechanism controlling resistance may differ in different populations of the same species as well as between different species. It is the versatility of species in their ability to adapt to insecticides which so greatly complicates the problem of control.

SUMMARY.—The development of resistance to DDT has been studied in populations of *Drosophila melanogaster* which were derived from inbred, laboratory, and wild stocks. The results indicate that the ability of a population to become more resistant to DDT is related to the amount of genetic variability in the original population. Furthermore, the failure of the hybrid populations from inbred and laboratory stocks to become more resistant indicates that not just any type of genetic variability, but the proper kinds of genes must be present for resistance to develop.

The development of resistance in the populations was directly related to the strength of the selection pressure, the higher concentrations of DDT being more effective in producing increased resistance. Resistance usually

increased most rapidly during the first few months of selection. Each stock tended to have a somewhat different level of resistance, for some of the controls differed from each other, and the resistant stocks also differed from each other as well as from their controls. The level of resistance in the populations did not remain static. For example, three populations which became more resistant later declined in resistance despite continued exposure to DDT.

The implications of the results are discussed in relation to the genetic mechanisms controlling resistance, the question of reversion to susceptibility on removal from DDT, and the amount of morphological and physiological change to be expected in association with resistance.

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BULLETIN OF THE ENTOMOLOGICAL SOCIETY OF AMERICA

Members should read this publication carefully! It sometimes contains announcements, notices, etc., not sent to the membership in any other way.

The Effects of Different Temperatures and Piperonyl Butoxide on the Action of Malathion on Susceptible and DDT-Resistant Strains of House Flies[1]

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The synergistic effects of piperonyl butoxide and pyrethrins are well known, although the biochemistry of the synergistic action has not been elucidated. With the advent of house flies showing a pronounced resistance to DDT, a search for synergists for this type of compound was undertaken (March *et al.* (1952)). Sumerford (1954) reviewed the literature on synergists for chlorinated organic insecticides. Eddy *et al.* (1954) investigated the use of synergists with phosphorus compounds against the body louse. Hoffman *et al.* (1954) presented the results of investigations with pyrethrum synergists combined with organic phosphorus insecticides. These workers found some indications of synergistic action of piperonyl butoxide with several organic phosphorus insecticides when tested against DDT-resistant house flies by a residual method. No positive effects were observable in combinations of piperonyl butoxide and malathion by this test method.

There have been numerous investigations of the effects of temperature on insecticide action. The test species, life stage, and method of administration appear to have a pronounced effect on the direction of the temperature coefficient of insecticide action (Woodruff 1950, McIntosh 1951, 1954). The concentration and formulation of the insecticide also affect the temperature coefficient (Richards & Cutkomp 1946, Fan & Cheng 1948). Vinson & Kearns (1952) found that the symptoms of DDT intoxication in American cockroaches could be reversed by changing the environmental temperature, i.e. cockroaches prostrate after DDT treatment at 15° C. could be revived by transfer to a 35° C. chamber. The effects of different temperatures on individual treatments with organic phosphorus compounds apparently have not been investigated.

The authors of this paper initiated an investigation of the action of piperonyl butoxide and three organic phosphorus compounds, Diazinon, Bayer L 13/59 and malathion, on two strains of house flies and the nature of the temperature coefficients of such combinations. It was observed that there was a small but significant difference in the tolerance of these two strains, (a DDT-resistant and a susceptible strain) to the compounds, both alone and in combination with the synergist. There was a significant synergistic effect of piperonyl butoxide with Diazinon and Bayer L 13/59, but there was a pronounced antagonism in the case of malathion plus piperonyl butoxide. The results of the investigations of this antagonistic action are presented in this paper. The results of the other investigations will be presented later.

MATERIALS AND METHODS.—Two strains of house flies, *Musca domestica* L., were used in these investigations. The strain designated as KUN has been reared in the laboratory with no previous history of insecticidal exposure. The strain designated as Campus was collected on the campus of Kansas State College in July 1954 and subsequently reared in the laboratory. An intensive fly control campaign had been employed for several years prior to this collection. The LD_{50}'s determined by topical application with a microloop were 3.0 and >600 micrograms of DDT per gram of flies for the susceptible and resistant strains, respectively.

These flies were reared in the laboratory in accordance with standard procedures of National Association of Insecticide and Disinfectant Manufacturers modified only with reference to the adult diet. Adult flies were provided with water and a mixture of non-fat powdered milk (2 parts) and cane sugar (1 part) in separate dishes. The rearing room was maintained at a temperature of $80 \pm 2°$ F.

Only 4-day-old male flies were used in these tests. The flies were anaesthetized with a minimum of CO_2 to facilitate handling while treating and were conditioned to the selected test temperature for 24 hours prior to treatment. The flies were removed from the test temperature for not longer than 5 minutes during the treatment period. The test temperature was maintained at the selected level to within $\pm 2°$ F.

The compounds used were malathion (99.6% pure) and technical piperonyl butoxide. All solutions were made up in glass-distilled acetone. Solutions of piperonyl butoxide and malathion were made up at a ratio of 10:1. Individual topical applications of 1.07 ± 0.05 microliters were made on the mesosterum of each fly. Mortality readings were taken periodically throughout the 24-hour observation period. Only the 24-hour readings are analyzed in this paper. Only the flies showing no visible movement were counted as dead.

Four dosage levels were used giving mortalities between 10 and 90%. Twenty-five flies were employed in each test. Each test was replicated four times. Tests on malathion or malathion plus piperonyl butoxide were run on the same lot of flies. All data presented were derived from statistical analyses. Although the calculated values differ from those determined from eye-fitted regression lines, the relative differences among the calculated data are consistent with those determined by less exacting means.

DISCUSSION.—The analysis of variance presented in table 1 indicates in summary form the statistical significance or lack thereof of the various factors and their interactions. These data indicate that there were significant differences in: (1) the effects of the malathion and the malathion plus piperonyl butoxide treatments; (2)

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Table 1.—Analysis of variance of LD_{50}'s determined at four temperature levels for two strains[a] of house flies treated topically with malathion or malathion plus piperonyl butoxide (1:10).

SOURCE OF VARIANCE	df	MEAN SQUARE
Toxicant effect	1	536.85[b]
Strain effect	1	523.26[b]
Temperature effect	3	139.06[b]
Interaction		
Toxicant×Strain	1	33.12[b]
Toxicant×Temperature	3	19.37
Strain×Temperature	3	1.12
Error	3	2.89
Total sum square	15	

[a] A DDT-resistant and a susceptible strain of house flies.
[b] Significant at 5% level.

the tolerance of the two strains of flies; (3) the effects of temperature; and, (4) the interaction of the strains and toxicant combinations. The other interactions were not significant.

The first order interaction presented in table 2 indicates clearly the differences in tolerance of the two strains of flies and the pronounced antagonistic effect of piperonyl butoxide on malathion for both strains of flies. The results presented in this table are based on the values determined for each strain at all four temperature levels, i.e. 63, 70, 75, and 82° F. The ratios of the response of the two strains to malathion and to the piperonyl butoxide-malathion combination are 1.54 and 1.58, respectively. The ratios showing the comparisons of the antagonistic effects are likewise of the same order of size. These comparisons suggest that the antagonistic effect is of the same order of magnitude for both strains. The addition of piperonyl butoxide increases the tolerance of the susceptible strain to a level directly comparable to that of the resistant strain to malathion alone. This suggests that the antagonistic mechanism involved is of the same nature in both the resistant and susceptible strains.

Although the greater tolerance of the DDT-resistant strain of flies for malathion is not unusual, the phenomenon of an actual antagonism from the use of piperonyl butoxide-malathion combinations is of considerable interest. The work of Hoffman *et al.* (1954) indicated some degree of synergistic action of piperonyl butoxide in combination with some organic phosphorus insecticides and no apparent effect with others. Unpublished data from this laboratory have confirmed the synergistic action with the compounds mentioned previously. The present investigations clearly indicate some specific differences in the mode of action of organic phosphorus compounds.

Table 2.—The first-order interaction between two strains of house flies and malathion or malathion plus piperonyl butoxide.[a]

	MALATHION		MALATHION PLUS PIPERONYL BUTOXIDE
KUN	62.63	**[b]	97.46
Campus	96.87	**	154.72

[a] Figures given are the sums of the LD_{50}'s in micrograms malathion per gram of flies for all temperature levels.
[b] Figures separated by asterisks are significantly different at the 1% level.

The effects of environmental temperature on the action of these compounds on the two strains of flies indicate a further similarity of the antagonistic actions involved, as well as the consistent difference in the response of the two strains to malathion throughout the temperature range studied.

Although the results of the analyses of the interactions of strain and temperature, or treatment and temperature, are not significant, tables 3 and 4, there are significant differences in the responses of these insects at the different temperature levels, table 5. The data in table 5, indicate that there are no significant differences in the LD_{50}'s between the 75 and 82° F. levels. These data indicate the desirability of extending the temperature range into higher levels to study the characteristic responses in these ranges.

Table 3.—The first-order interaction between two strains of house flies treated with malathion or malathion plus piperonyl butoxide and the four temperature levels investigated.[a]

	63° F.	70° F.	75° F.	82° F.
KUN	53.46	42.11	31.70	32.82
Campus	80.91	65.00	51.46	54.22

[a] Figures given are the sums of the LD_{50} in micrograms of malathion per gram of flies for both types of treatment.

Table 4.—The first-order interaction between malathion or malathion plus piperonyl butoxide and the four temperature levels investigated.[a]

	63° F.	70° F.	75° F.	82° F.
Malathion	48.92	44.01	33.62	32.95
Malathion + piperonyl butoxide	85.45	63.10	49.54	54.09

[a] Figures given are the sums of the LD_{50}'s in micrograms of malathion per gram of flies for both strains tested.

The interactions between strains and temperatures shown in table 3 indicate that the response of the two strains to the various temperature levels are of the same order, differing only quantitatively due to the tolerance differences inherent in the strains. The Campus strain is considerably more resistant at all temperatures. It is interesting to note that an increase in temperature results in a decrease in the value of the LD_{50} for both strains, i.e. a positive temperature coeffiicent.

Although the interactions between treatments and temperatures as shown in table 4 do not show the degree of significance apparent in other data, they are significant at the 0.10 level. Apparently at least two mechanisms are involved, the action of piperonyl butoxide having one temperature coefficient and the toxic effects of malathion another.

The LD_{50}'s and their confidence intervals at the 0.05 level for both strains with the two treatments at all four temperature levels appear in table 6. These data indicate the differences in the response between the two strains of flies to both treatments and the differences in response

Table 5.—Descending array of the means of the LD_{50}'s for both strains and treatments at the different temperatures.

TEMPERATURE (° F.)	LD_{50}[a]	N
75	20.79	4
82	21.76 [b]	4
70	26.78 [b]	4
63	33.59	4

L.S.D. = 3.82 at the 0.05 level.
[a] These values in micrograms of malathion per gram of flies.
[b] Significant at the 5% level.

to the treatments within the strains. The confidence intervals also provide an interval within which the true LD_{50} is likely to lie. They were calculated from the formula given by Anderson & Bancroft (1952), page 164.

The data in table 6 represent a complete summary of the dosage mortality data and an indication of the effects of the various factors and combinations that have been analyzed and discussed previously.

To completely evaluate data of this nature, it is desirable to have available at least one additional statistic, the slope *b* of the regression lines from which the LD_{50} values were obtained. These values have been tabulated

Table 6.—The LD_{50}'s[a] and their 95 per cent confidence intervals at the 0.05 level for two strains of house flies treated topically with malathion or malathion plus piperonyl butoxide (1:10) at four different temperatures.

	CAMPUS[b]		KUN[c]	
	Malathion	Malathion + Piperonyl Butoxide	Malathion	Malathion + Piperonyl Butoxide
63° F.	30.12	50.79	18.80	34.66
CI_{95}	26.85–33.65	38.02–62.81	18.39–20.53	30.89–45.58
70° F.	26.44	38.56	17.57	24.54
CI_{95}	22.34–27.33	34.44–43.55	13.81–17.62	23.52–28.11
75° F.	20.75	30.71	12.87	18.83
CI_{95}	19.41–21.63	27.38–34.28	11.93–13.43	16.70–26.66
82° F.	19.56	34.66	13.39	19.43
CI_{95}	17.86–23.88	31.99–37.76	12.63–14.79	17.32–21.38

[a] Micrograms of malathion per gram of flies.
[b] A DDT-resistant strain of flies.
[c] A susceptible strain of flies.

Table 7.—The estimated slope, *b* of the regression lines for two strains of house flies under two treatments and at four temperature levels.

TEMP. ° F.	CAMPUS Malathion		CAMPUS Malathion + Piperonyl Butoxide		KUN Malathion		KUN Malathion + Piperonyl Butoxide	
63	6.23	a	3.25 [a]		9.22 [c]	b	6.04	
70	7.24 [b]		5.74		15.87 [a]	c	8.49 [c]	
75	12.41 [c]	c	5.85		10.92 [a]	c	3.15 [b]	
82	4.48	b	7.97		8.26		7.62	

[a] Significant difference at the 5% level.
[b] Significant difference at the 1% level.
[c] Significant difference at the 0.1% level.

in table 7. The significance of differences between these slopes also is indicated in this table. Where no notation appears, the difference between the slopes is not significant.

In both strains the slopes for piperonyl butoxide-malathion combination are less than for the malathion alone. The exception to this in the 82° F. level for the Campus strain is difficult to explain. From these data it would appear that the general mechanisms of intoxication differ markedly for the two treatments. In the majority of cases there are significant differences in the slopes with reference to strain, treatment, or temperature.

SUMMARY.—The lethal effects of individual topical applications of acetone solutions of malathion and malathion-piperonyl butoxide combinations were investigated. The test insects were a DDT-resistant and a susceptible strain of house flies, *Musca domestica* L.

Four temperatures, 63, 70, 75, and 82° F. were used for each strain and treatment. Regression lines were determined by the method of least squares. All data were statistically evaluated. There were significant differences in the effects of the two treatments, the responses of the two strains, and the effects of temperature at the different levels. There was a significant interaction between strain and treatment. The interaction between treatments and temperatures was only significant at the 0.1 level.

The calculated LD_{50}'s and their confidence limits at the 0.05 level for strains, treatments, and temperatures as well as the slopes *b* of the regression lines are presented. In general the slopes for the combination of piperonyl butoxide and malathion are less than those for malathion alone for both strains and all temperatures. The antagonism of malathion's lethal action by piperonyl butoxide and the differential response to the two treatments at certain temperature levels affords additional possibilities for investigating the mode of action of malathion and piperonyl butoxide.

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Reproductive Potential, Longevity, and Weight of House Flies which Survived one Insecticidal Treatment[1]

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Since the development of house fly resistance to chlorinated insecticides, investigations have been directed primarily toward the determination of the degree of resistance to the insecticides, whether or not resistance to one insecticide carries over to another, and on genetic and physiological studies on the nature of this resistance.

It has been suspected for some time by the writers that alterations in the biology of insects may accompany the establishment of resistance to insecticides. Knutson (1955) reported that *Drosophila melanogaster* Meigen adults which survived dieldrin treatment produced 5.8% more mature progeny than the untreated flies, and included a literature review on modifications in biology associated with insecticide treatment, largely arsenicals and cyanides rather than organic insecticides.

Recent references include the record that the European red mite, *Metatetranychus ulmi* (Koch), demonstrated a higher reproductive rate as the result of DDT treatment (Hueck *et al.* 1952). The Public Health Service reported (Anon, 1955) that privies which were a poor source of house flies before residual treatment became an increasingly important source following treatment. This increase was most pronounced when dieldrin was used. DDT deposits resulted in only slight increase in propagation. Limited tests with BHC and lindane produced an increase of less magnitude than dieldrin. The house flies were resistant to the above insecticides in all cases.

This investigation measured the effect of a single insecticidal treatment upon the biology of the parent and upon the first three filial generations.

METHODS AND TECHNIQUES.—The laboratory strain of the National Association of Insecticide and Disinfectant Manufacturers, with no history of insecticide exposure, was used. Rearing occurred at 80° F. and about 50% relative humidity. Flies were immobilized for manipulation with a continuous stream of carbon dioxide. Within 12 hours after emergence, the sexes were separated in order to prevent mating (Dunn 1923).

The flies were supplied daily with small cups containing cotton soaked with a solution consisting of 13 fluid ounces of evaporated milk diluted with enough water to made a gallon of liquid, to which 2.5 ml. of 40% formaldehyde solution were added to delay souring.

When 3 to 4 days old, the experimental flies were treated with dieldrin[3] in acetone solution, applied by calibrated micro-loop to the thorax while immobilized with carbon dioxide. The dosage used was 2 microgm./gm. of flies (Bruce & Decker 1950), found previously to produce a mortality of 60 to 90%. Topical application was used to assure maximum uniformity of dosage. The flies were then held for 2 days until all mortality resulting from insecticide exposure had occurred. The surviving flies were then separated into 20 replicates consisting of 10 females and six males each. Each replicate was placed in a quart glass jar with a screen top. Untreated flies, identical to the experimental flies except for no dieldrin treatment, were divided into similar replicates to serve as controls.

Each jar was supplied daily with a paper cup containing cotton soaked in fresh milk to provide food and to serve as the oviposition substratum. The paper cups containing eggs were removed daily to other jars with screen tops, containing NAIDM standard larval medium. Tap water was added to the paper cup before it was placed in the larval medium to provide sufficient moisture for hatching and to prevent pupation in the cotton. The rearing jars were held until all adult emergence (F_1 generation) had occurred. This provided a daily record of the number of adult offspring produced by each of the 20 replicates of the experimental and control groups.

F_1 adults resulting from eggs laid in the fifth and sixth days from initial mating of parent flies served as the source of the F_2 generation. Two days after emergence, 10 females and 10 males of this generation were taken at random from each replicate and introduced into jars; this resulted in 20 replicates. The F_3 generation was obtained in the same manner as the F_2. In selecting flies for these successive filial generations, the 10 females and males selected from each group were taken as nearly as possible from rearing jars in which equal numbers of pupae had developed to eliminate possible differences produced by crowding.

In addition to the production data, longevities and weights after death of the female parents and progeny were recorded.

The untreated flies and the flies treated with dieldrin are referred to as the "Untreated parents" (UP), and "Treated parents" (TP), respectively. Their progeny are desiganted as UF_1 and TF_1, respectively. Progeny

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[3] Recrystallized, sample No. 3219, Julius Hyman Co.

of the UF_1 and TF_1 are designated as UF_2 and TF_2; and their progeny designated as UF_3 and TF_3. The TP (parent) generation was the only group treated with the insecticide.

RESULTS AND CONCLUSIONS.—Table 1 shows that the untreated parents produced a total of 4,795 adult offspring and the dieldrin-treated parents produced a total adult offspring of 5,594, representing a 16.7% greater progeny in dieldrin-treated flies. The number of progeny probably was relatively low in both groups because neither was allowed to mate until 5 to 6 days of age.

Measurable reproduction in the first filial generation was confined to the first 13 days following initial mating because, unfortunately, on the fourteenth day, the surgical cotton normally used in feeding the flies was accidentally replaced with fireproof cotton which had been treated with poisonous chemicals. As a result, most of the flies died immediately after the thirteenth day. However, the data for the first 13 days are sufficient for this study since the principal period of reproduction, as can be observed for the untreated flies in table 1, is well within the first 13 days of life. Table 1 shows that the UF_1 generation produced a total of only 10,816 flies, while the TF_1 produced a total of 18,361 flies, a 69.2% increase.

The data in table 1 show that the UF_2 and TF_2 generations produced a total progeny of 15,258 and 16,679, respectively, representing a 9.3% greater progeny in dieldrin-treated group. The UF_3 generation produced 9,716 flies, while the TF_3 generation totaled 8,569 flies. This represents 13.4% greater progeny from the UF_3 generation than from the TF_3 generation.

Table 2 presents an analysis of variance to detect possible significant differences between treated and untreated flies, based upon the mean number of adult progeny produced by a single female fly per day; days after oviposition ceased are not included in this calculation. Means are based upon an average of all lot replications.

No significant difference occurred between the treated and untreated parents; however, it cannot be determined by this study whether or not a significant difference actually occurs under normal life history conditions because of the necessity of introducing artificial conditions by postponing mating 5 to 6 days in order to allow time for flies to age and also to allow time for the susceptible flies to succumb to the insecticide. What effect this postponement may have on the reproductive potential is not known. It is known (F_1, F_2, F_3 of Table 1) that this period of 5 or 6 days represents a substantial part of the total progeny production when mating is not postponed. Further evidence that this postponement may distort the actual picture under natural conditions is provided by the fact that the parent flies which survived the sublethal amount of insecticide may have exhibited apparent toxic effects of the insecticide during the first week (Table 1); this was evidenced by a reduction in reproduction (2,803 adult progeny) compared with the untreated flies (3,061 adult progeny). This phenomenon was reversed during the same period in the F_1 (UF_1, 6,026 adult progeny; TF_1, 10,540 adult progeny). However, in the literature, there are accounts of instances where female insects, after being subjected to an insecticide, oviposited at an abnormal rate. In the case of this study, however, the surviving flies received a sublethal dosage. This dosage may have produced sufficient intoxication to induce the abnormal oviposition referred to above.

Further evidence that there may be an actual increase in progeny of dieldrin-treated parents under normal mating conditions is suggested by the fact that the number of F_1 adult progeny (Table 2) was 10.75 per female fly-day compared with 6.82 in the untreated flies. This is a significant difference. The UF_2 and TF_2 progeny were not significantly different; the same was true of the F_3. Thus reversion to normal reproduction totals occurred in the F_2 and F_3 generations. Such reversion might be expected because of the limited selection of this characteristic provided by only one treatment of the insecticide. It is surprising, however, that this characteristic of increased reproductive rate which was evident in the F_1 should disappear so rapidly.

The increased progeny production in the F_1 of the treated flies was undoubtedly the result of selection of more vigorous parents by the insecticide. Apparently the insecticide killed flies with a lower survival potential to the toxic insecticide used, and there was a temporarily greater reproductive potential associated with those flies with a greater survival potential.

It will be noted that there is a difference in number of adult progeny produced among the various generations (Table 2). These differences, however, did not affect the

Table 1.—Number of living female parents, F_1, F_2 and F_3 generations and their respective adult progeny during successive weeks throughout productive life under controlled laboratory conditions.

	Untreated		Treated	
Successive Weeks Following Mating	No. of Living ♀♀ Remaining (per 100 ♀♀)	Resulting Adult Progeny (per 100 ♀♀)	No. of Living ♀♀ Remaining (per 100 ♀♀)	Resulting Adult Progeny (per 100 ♀♀)
	UP	*Parent Generation*	TP	
1	79	3,061	83	2,803
2	53	1,186	56	1,706
3	33	346	33	870
4	16	141	15	233
5	0	61	0	45
Totals	—	4,795	—	5,594
	UF_1	*First Filial Generation*	TF_1	
1	96	6,026	99	10,540
2 (13 days)	85	4,790	92	7,821
Totals[a]	—	10,816	—	18,361
	UF_2	*Second Filial Generation*	TF_2	
1	98	7,631	98	8,027
2	85	4,718	90	5,461
3	63	2,390	70	2,208
4	41	410	46	322
5	22	68	23	503
6	11	35	13	38
7	8	3	5	8
8	2	3	2	24
9	0	—	1[b]	56
Totals	—	15,258	—	16,679
	UF_3	*Third Filial Generation*	TF_3	
1	92	7,871	92	7,103
2	81	863	76	486
3	59	461	52	519
4	31	425	34	244
5	13	7	21	54
6	5	39	6	28
7	1[c]	50	1[d]	135
Totals	—	9,716	—	8,569

[a] Records for only first 13 days following mating.
[b] One fly lived into the 11th week, producing at the rate of 32 progeny per 100 females.
[c] One fly lived into the 8th week, but produced no progeny.
[d] One fly lived into the 9th week, but produced no progeny.

Table 2.—Analysis of variance of average number of adults produced per female fly-day[a] between the treated and untreated house flies.

SOURCES OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE
Generations and treatments	7	117.29[b]
Lots, same generation and treatment	120	6.92
Total	127	

Ordered Array of Generation and Treatment Means

Generation-Treatment[c]	Mean	N
TP	3.23	20
UP	2.81	20
TF_1	10.75[d]	17
UF_1	6.82[d]	18
TF_2	5.78	14
UF_2	5.77	15
UF_3	4.01	12
TF_3	3.52	12

[a] Days after oviposition ceased are not included in this calculation.
[b] Significant at the 0.1% level.
[c] U = untreated; T = treated.
[d] L.S.D. = 1.76, significant at 5% level.

results of this study because the treated and untreated groups underwent the same procedure during each generation.

The average longevity of the flies in days was as follows: TP, 17.1; UP, 16.8; TF_2, 28.4; UF_2, 27.1; TF_3, 23.7; UF_3, 23.9. Statistical analysis showed no significant differences between treated and untreated generations. Longevity in the F_1 generation could not be measured since, as mentioned previously, it was necessary to terminate the F_1 rearings at 13 days. Of interest is the fact that differences in longevity in the UF_2 generation, compared with the UF_3 (L.S.D. at the 5% level = 3.78 days), almost approached significance. No explanation for this can be advanced, since the dieldrin-treated and the untreated flies of each generation were manipulated identically, so that no interference could occur that would affect this study. Also of interest is the fact that the F_3 generation was significantly longer-lived than the parent generation (L.S.D. at the 5% level = 3.56 days); the fact that the parent flies were held 5 to 6 days before mating may have been an influencing factor in this case.

The mean number of days from initial oviposition until all egglaying had ceased was as follows: TP, 22.4; UP, 23.2; TF_2, 39.4; UF_2, 38.6; TF_3, 30.7; UF_3, 30.4. Admittedly, this is of limited value, since the laying of of one final egg after an interval of 10 eggless days would, for example, add 11 days to the total oviposition period of the fly, while actually this one egg would represent only a very insignificant portion of the total oviposition. Statistical analysis showed no significant difference between the treated and untreated flies. Of interest, although of no significance in this study, was the existence, similar to the longevity data, of a significant increase in the numbers of days in both the untreated and treated groups between the F_2 and the F_3 generations (L.S.D. at the 5% level = 7.89). There was also a significant difference between the numbers in the F_3 generation and of the parents (L.S.D. at the 5% level = 7.44). In this case, however, the low figure in the parental generation was to be expected since they were held 5 to 6 days before being allowed to mate.

The average weight of females at death, in mg., was as follows: TP. 17.1; UP, 15.9; UF_2, 19.5; TF_2, 21.1; TF_3, 21.7; UF_3, 21.9. The differences in weights in the untreated and treated parents reached near significance (L.S.D. at the 5% level = 1.32). In the F_2, the treated flies produced significantly heavier females compared with the untreated flies (L.S.D. at the 5% level = 1.42). No significant difference occurred in the F_3. Difference in weight in the parent generation may have been the result of a greater amount of toxicant per body weight of fly, since all flies were given the same size dosages. Differences in weights in the F_1 generation could not be measured because of the laboratory accident referred to above. Apparently, differences in body weight continued through the F_2 generation but disappeared in the F_3.

Average numbers of adult progeny per female fly per day, average weight, and average longevity were analyzed by linear correlation coefficients. A linear correlation was found between the weight of the dieldrin-treated parent females and the number of progeny produced by these females. However, this correlation was not significant in the first, second, and third generations of the dieldrin-treated female flies. It was not significant also in the untreated parent female flies and their three generations. The correlation between the length of life and the average weight in either the dieldrin-treated female flies and their generations or in the untreated female flies and their generations was not significant. The correlation between the length of life and the number of progeny of the treated and untreated groups produced was not significant in any respect.

SUMMARY.—This study was concerned with the effect of a single insecticidal treatment upon the biology of an insecticide-susceptible parent generation of house flies and their subsequent three filial generations.

A susceptible NAIDM strain of house flies, when 3 to 4 days old, was treated with dieldrin at a concentration to produce 60 to 90% mortality. Surviving flies were held 2 additional days, until all mortality resulting from insecticidal treatment had occurred. These 5- to 6-day-old flies were then allowed to mate. The dieldrin-treated parent generation, during the first week, produced only 2,803 adult offspring compared with 3,061 in the untreated controls. This is thought to have been the result of the direct effect of the toxicant. Subsequently, the dieldrin-treated group excelled the controls so that the final total of adult progeny was 5,594 and 4,795 respectively. Statistical analysis of variance indicated no significant difference. This does not necessarily preclude a significant difference under natural conditions, because of (1) the postponement of mating 5 to 6 days, which period constitutes a substantial portion of the normal reproductive period, and (2) the initial lag after mating of nearly a week in productivity in the dieldrin-treated flies.

The F_1 generation of the treated parents produced at the rate of 18,361 adult progeny per 100 females compared with 10,816 by the F_1 untreated parents, during the first

13 days after initial mating. This was a 69.2% increase, which is a significant difference. A laboratory accident prevented measurement of the number of progeny after the thirteenth day, but the great majority of oviposition is normally completed by the thirteenth day.

The F_2 generation of the treated parents produced adult offspring at the rate of 16,688 per 100 females compared with 15,268 in the untreated flies. This represented a 9.3% increase. The F_3 of the treated parents produced 8,569 adult offspring compared with 9,716 in the untreated. This was a 13.4% difference. In both instances, these differences were not significant, indicating a reversion to the normal rate of reproduction.

Although the life span of the females was longer in the treated parents as well as in its F_2 and F_3 generations, statistical analysis of variance showed no significant difference in longevity. The same was true when comparing relative lengths of oviposition periods.

Treated parents approached significantly greater weights than the untreated parents. Adults of the treated F_2 generation were significantly heavier than those of the F_2 untreated group.

A linear correlation was found between the weight of the treated parent females and the number of progeny produced by these females. However, this correlation was not significant in the first, second, or third generation of the treated group. It was not significant also in the untreated parent females and their three generations. The correlation between length of life and the average weight was not significant in either the treated or the untreated parents and in their respective generations. The correlation between length of life and the number of progeny produced was not significant.

Results obtained have prompted field studies currently being conducted to determine if differences may persist when repeated insecticidal applications occur.

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A Chemically Defined Medium for Rearing *Aedes aegypti* Larvae[1]

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In considering the history of the development of a chemically defined medium for an aseptic culture of larvae of *Aedes aegypti* (L.), two investigations stand out, that of Trager (1948) and of Golberg & DeMeillon (1948). Both groups had been studying this problem for a number of years and each had made important contributions toward a chemically defined larval medium. Trager, whose 1948 work dealt with the role of vitamins, used casein as a protein source for the larvae. Golberg and DeMeillon studied a diet of amino acids plus some vitamins. However, yeast antolysate had to be included in the medium for growth of the larvae, and attempts to replace the yeast with additional vitamins failed. Neither group could be considered to have used a completely defined medium. Recently, two nutritional studies of dipterous insects reared from egg to adult in chemically defined media have been reported, *Drosophila* by Hinton *et al.* (1951), and *Pseudosarcophaga affinis* by House (1954).

EXPERIMENTAL PROCEDURE.—One phase of the research on the nutrition of adult *Aedes aegypti* in progress in this laboratory, required the use of a chemically defined medium for rearing the larvae under aseptic conditions. Despite Golberg's failure, the problem seemed to be simply a matter of combining Trager's vitamin mixture and the amino acid component of Golberg's medium.

Several months of unsuccessful trials with such a diet showed that the problem was more complex than anticipated. Larvae remained alive for some weeks in the medium but failed to grow beyond the first instar. From the appearance of the larvae, it seemed that all that the medium lacked was some essential growth factor. Several such factors considered essential or stimulatory were included in the media: ascorbic acid, used by Lichtenstein (1948) for rearing *Culex molestus*, vitamin B-12 added to the *Drosophila* medium of Hinton, and orotic acid which was found by Hauge (1953) to promote growth of *Lactobacillus bulgaricus* 09. However, none of these made any improvement in the media. During these experiments, it was observed that pH adjustment was of considerable importance; too high or too low a pH killed the larvae soon after hatching. All subsequent media were adjusted to pH 6.5 to 7.0 before sterilization.

Finally, it was suspected that the osmotic pressure re-

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sulting from the amino acids, salt mixture, and sugar in solution might be inhibiting the development of the larvae. To overcome this factor, the amino acids, salts, sugar, lipid, and ribonucleic acid were dissolved together in water, and agar, about 1%, was mixed with this part of the medium. When this agar medium had solidified after autoclaving, distilled water containing a vitamin mixture was sterilized by filtration through a Seitz filter, and this sterile solution added on top of the agar medium. Thus, the young larvae could, by feeding on the agar, obtain the amino acids and the other soluble components which were at least delayed, by being in agar, from diffusing into the liquid part of the larval medium.

The larvae grew in this medium, although growth was slow, and other problems still remained. The formulation of the amino acid mixture was changed to one based on the results of studies in adult mosquito nutrition carried out in this laboratory by Dimond *et al.* (1956). This speeded up the growth, as did an increase in the concentration of the ribonucleic acid. Also the vitamins were combined directly into the agar part of the medium before autoclaving, and sterile water alone was added on top of the agar. At this point the time required from hatching to pupation was shortened from 3 to 2 weeks.

The only problem remaining was that only occasionally was an adult found alive resting on the sides of the rearing bottle. Most of the adults which emerged were found dead on the surface of the media. This phenomenon was noted by Golberg using cystine deficient diets, and by ourselves whenever casein, which is known to be low in cystine, was used as the source of protein for the larvae. The quantity of cystine in the media was increased several times, but when the pH was adjusted to neutrality, the cystine did not remain in solution. Cysteine was tried as a supplement and a replacement for cystine, but the adults were still found dead in the media. It was then realized that the chemical composition of the test media was not at fault, but rather, the adults emerging in the small rearing bottles became "trapped" or "bogged down" and died in the media, which after 2 weeks had become somewhat viscous. Adults emerging from pupae taken from sterile nutrient media and placed in clean water in a non-sterile cage flew about in the cage, mated, took a blood meal, and laid viable eggs. Using aseptic technique, pupae were also transferred to sterile water where the adults emerged successfully and did not die on the surface of the water. Therefore, this medium is considered adequate for growth of *Aedes aegypti* larvae from egg to normal adults.

Obtaining aseptic eggs.—Eggs in the laboratory stock colony of *Aedes aegypti* are laid on moist strips of paper toweling and are then properly aged and stored by drying the strips between paper toweling. To obtain aseptic larvae, *Aedes* eggs were surface sterilized by the following procedure. The dried eggs were scraped off the toweling and several hundred placed in a piece of glass tubing (a 1 ml.-section of a 5 ml.-pipette) covered at one end with fine mesh nylon. This tube with the eggs was submerged for 2 minutes in a beaker containing a solution of:

9. ml. clorox
1 ml. Roccal
40 ml. distilled water

During this period the eggs were withdrawn into a blunt eye-dropper and then forced back into the original tube. This was repeated several times during the 2 minutes in the clorox solution. The tube and eggs were then transferred to another beaker of 75% alcohol. The eggs were agitated again several times with the dropper. After 5 minutes in this bath, the alcohol was poured off, the eggs drained of excess alcohol, and the beaker and tube laid on their side. Using a small wire spatula, a few eggs were transferred to each rearing bottle containing the sterile test diet. Transfers could be made for a period of 15 to 20 minutes after the alcohol bath without noticeable effect on hatch of the larvae. Although the number of eggs added to each bottle was not constant in these preliminary tests, there was an excess of food available for the

Table 1.—Composition of stock mixtures used to prepare chemically defined medium for rearing *Aedes aegypti* larvae.[a,b]

Stock Mixtures					
Amino Acid	Mg.	Vitamins	Mg.	Sugar-Lipid-Salts	Mg.
DL Alanine	300	Biotin	0.05	Glucose	2,000
L Arginine[c]	500	Calcium pantothenate	15	Cholesterol	200
L Aspartic acid	200	Choline chloride	50	Wesson's salt mixture	500
L Cysteine[c]	800	Glutathione	25	Ammonium acetate	500
L Glutamic acid	1,250	Nicotinamide	25		
Glycine	700	Nicotinic acid	5	(Dissolved in 500 ml. distilled water)	
L Histidine[c]	200	Pteroylglutamic acid	10		
DL Isoleucine	650	Pyridoxine HCl	10		
L Leucine	800	Riboflavin	10		
L Lysine[c]	800	Thiamine HCl	10		
DL Methionine	200	(Dissolved in 50 ml. distilled water)			
DL Phenylalanine	1,500				
L Proline	200				
DL Threonine	400				
L Tryptophane	400				
L Tyrosine	200				
DL Valine	1,250				

[a] The quantity of each stock mixture used and the method of preparation are given in the text.
[b] Ribonucleic acid and agar are included in the medium but not in the stock mixtures. See text for details.
[c] Monohydrochloride.

larvae. The rearing bottles used were 1-ounce French square bottles plugged with cotton. At least five replicates of each test diet were set up.

Preparation of the medium.—In table 1 the components of the stock mixtures and the amounts used are listed. Each larval rearing bottle contained 5 ml. of nutrient solution, solidified in the bottom by the addition of agar. Preparation of the medium was carried out by the following procedure:

1. The amino acids were weighed and ground together in a mortar.
2. The carbohydrate and salts were dissolved in 500 ml. of distilled water to which was added a solution of the cholesterol in 5 ml. of 95% alcohol. The cholesterol made a poor suspension which had to be shaken vigorously before use. Attempts to stabilize it with Tween 80 appeared detrimental to the larvae at the concentration used so the Tween 80 was omitted in the final medium.
3. The stock solution of vitamins was made up in 50 ml. of distilled water.
4. The amino acid mixture was used at the rate of 25 mg. dissolved in 0.9 ml. of salt-sugar-lipid (SSL) solution.
5. Five mg. of ribonucleic acid were dissolved in a small amount of 0.2N NaOH and added to the amino acid-SSL solution. Heating this mixture helped to completely dissolve the soluble components.
6. Next, 0.1 ml. of the vitamin stock was added, and the mixture brought to pH 6.5–7.0 by the addition of NaOH.
7. Ten mg. of agar were added per ml. and the medium brought to a boil.
8. Five ml. of the medium prepared in this way were then added to each rearing bottle. These were plugged and autoclaved for 15 minutes at 20 lbs. pressure.
9. After autoclaving, the rearing bottles were cooled rapidly and shaken to prevent the settling-out of the components in suspension and to assure their uniform distribution throughout the solidifying medium.
10. When the nutrient agar medium hardened, 5 ml. of sterile distilled water (pH 6.5–7.0) were pipetted into the bottles on top of the agar.
11. Surface sterilized eggs were added to each bottle and all bottles placed in a covered plastic refrigerator crisper to prevent evaporation of the liquid. The bottles were held at about 82° F. and the developing larvae examined periodically. Aseptic techniques were used throughout the procedure, and checks for contamination were made using nutrient broth.

The chemically defined medium, as described, is not necessarily the optimum medium for larval growth. On this medium the time from hatch until the first larvae pupate varies between 11 and 13 days. Several of the components can undoubtedly be dropped without affecting development. Once the optimum quantities of each of the essential components have been determined, the time from egg to adult should be even shorter. By using only the components found to be essential for growth, it may also be possible to omit agar from the medium and rear the larvae on a medium in which all the constituents are in solution or suspension. These points and others are being investigated in order to determine more exactly the nutritional requirements for growth of *Aedes* larvae.

SUMMARY.—A chemically defined medium is described in which the larvae of *Aedes aegypti* can be reared aseptically to adults. The medium consisted of a mixture of amino acids, a salt mixture, glucose, cholesterol, ribonucleic acid, and a vitamin mixture dissolved or suspended in water. Agar was added to the medium prior to sterilization, and on cooling, the agar along with the nutrients were solidified in the bottom of small rearing bottles. Sterile water was added on top of the agar medium and surface-sterilized eggs introduced aseptically into the water. The larvae fed on the nutrient agar in the bottom of the bottle and pupated in slightly less than 2 weeks. The pupae transferred to sterile water emerged successfully and appeared normal.

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TENTH INTERNATIONAL CONGRESS OF ENTOMOLOGY

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Behavior of Angoumois Grain Moth on Several Strains of Corn at Two Moisture Levels[1,2]

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With the current increasing emphasis given the production and marketing of grain free from insect attack, the study of stored-grain pests is receiving augmented impetus. Direct methods of control by insecticides and other methods are being explored to determine what further contributions might be made to the improvement of stored grain pest control techniques. In view of the inadequacy of present control techniques and of the proposed sanitary standards for market grain, it seemed appropriate to examine the behavior of a grain infesting insect when reared on grains of different strains of the same host species. Detection of a variable response in the behavior of a grain infesting insect to host strains would suggest the possibility of producing varieties unfavorable to the development of the grain insects. To determine the logic of such reasoning a study of the Angoumois grain moth, *Sitotroga cerealella* Oliv., was conducted.

Some observations have been made of the differential responses of other grain insects when reared on strains of the same host (Richards 1944, 1948; Ali 1950; Williams 1954). Simmons & Ellington (1933) observed that the Angoumois grain moth was larger when reared on corn than on wheat. They considered females reared on corn more prolific because of their greater size. Lamb studied differential infestation by the Angoumois grain moth on ear corn of different inbred lines; (Data on file in the Department of Entomology, Kansas State College). Painter (1951) summarized much of the data relating to differential responses in insects including grain insects, to different hosts or host varieties in terms of growth and development.

METHODS AND MATERIALS.—Stock cultures of Angoumois grain moth adults were maintained in the laboratory at 82°±1° F. and at 70±2% RH. Oviposition was obtained by the method of Ellington (1930).

The samples of corn subjected to infestation represented 29 open-pollinated, single-cross hybrids derived from 14 parental inbred lines. Five of these inbreds served as both male and female parents; the other nine only as male or female parent.

The corn samples were screened over ¼-inch mesh screen to remove chaff, small kernels, and other undesirable debris. Three 168-gram samples of each hybrid were placed in 4- ×5½-inch muslin Bemis mailing bags. One sample of each variety was then placed in a 375-pound bulk of corn, in each of three barrels, the respective moisture levels of which were adjusted to 15, 17, and 21% to accomplish moisture stabilization. A six-weeks-period of stabilization was allowed prior to infestation of the samples.

Following the moisture stabilization period, each sample of corn was transferred to a wide-mouth, pint fruit jar and infested by placing in each jar cardboard oviposition strips with 600 newly deposited eggs of the Angoumois grain moth. The metal cap was inverted on each jar to allow passage of air and to avoid condensation of moisture in the jar. Determination of the moisture content of the grain was made by a Steinlite moisture tester, Model S. The corn labeled 14% moisture actually contained 14.15±0.81% and that labeled 17% contained 17.58±0.87%.

After infestation, the test samples were held in a constant temperature and humidity cabinet at 82°±1° F. and 70±2% RH. The egg stage had been observed by other workers to range from 4 to 9 days (Koone 1951; King 1918; Simmons & Ellington, 1924). Accordingly the cardboard oviposition strips were removed from the jars 10 days after infestation and the percentage of eggs hatching determined by counting the unhatched and/or sterile eggs. During the period between hatching and adult emergence excessive mold developed in the corn samples with 21% moisture. This lot was discarded after hatching records were taken. Light mold developed in some of the jars holding corn at the 17% moisture level.

The jars holding the corn samples were inspected daily, beginning the 20th day following infestation. When emergence began, the adults were removed daily. Manipulation and collection of the adults were accomplished in a small transfer cage 14×15×15 inches. Top and front of the cage were of glass, other surfaces of ¼-inch plyboard. Arm holes with sleeves through either side made possible the entry of hands and collecting equipment, yet prohibited escape of moths. The moths were collected with an aspirator operated from a Cenco vacuum pump. The first 20 specimens of each sex emerging from each sample were anesthetized with ethylene dichloride immediately after they were collected and weighed individually on a Roller-Smith balance calibrated to 0.1 mg. This technique provided weight records of adults from the different hybrids at the same relative period of development. Weights were taken of moths appearing later in the emergence period from randomly selected samples. When weight records from each sample were complete, four or more oviposition chambers containing approximately 10 moths each were established from each hybrid at each moisture level. Data on the period from egg to adult and sex were recorded for each moth emerging from the test hybrids until emergence was complete.

RESULTS AND DISCUSSION.—*Effects of the various hybrids on moth development and behavior.—Weight of adults.*—The average weights of the first 20 females and 20 males emerging from each of the 29 single cross hybrids maintained at 14 and 17% moisture are presented in table 1. They are ranked from highest to lowest according to average weights of females reared from the 14% moisture corn. The range of average weights of females from 14% corn was from 5.83 mg. (K4×oh7B) to 4.21 mg. (oh7B×K711). The average weight of males from the same samples ranged from 3.49 mg. (K4×oh7B) to 2.43

[1] This study was conducted in partial fulfillment for the degree, Doctor of Philosophy in Entomology, Kansas State College, Manhattan, and was supported in part by Kansas Agricultural Experiment Station, Bankhead-Jones Project 322 under the direction of Professor, D. A. Wilbur.

[2] Contribution No. 645, Department of Entomology, Kansas Agricultural Experiment Station, Manhattan. Accepted for publication November 9, 1955.

Table 1.—The average weight of 20 females and 20 males of the Angoumois grain moth reared on grain from 29 single cross hybrids at each of two moisture levels and the average number of eggs obtained from females reared on each hybrid.

Hybrid	Weights of Moths (mg.)				Oviposition of Moths			
					From 14% Moisture Corn		From 17% Moisture Corn	
	From 14% Moisture Corn		From 17% Moisture Corn					
	Female	Male	Female	Male	No. of Females	Average No. Eggs per Female	No. of Females	Average No. Eggs per Female
K4×oh7B	5.83	3.49	6.00	3.10	20	36.5	21	16.8
K707×K711	5.51	3.39	5.48	2.81	22	49.9	21	37.2
oh7B×K706	5.49	3.02	5.11	2.73	22	18.0	17	33.3
C.I.7×oh7B	5.46	3.32	5.22	2.73	17	47.4	18	16.2
K711×K712	5.37	3.15	5.10	2.71	18	45.2	18	21.0
C.I.21E×oh7B	5.34	3.03	5.92	3.20	20	23.9	23	29.5
C.I.7×K712	5.28	2.78	5.36	3.01	21	71.8	21	27.4
C.I.7×K711	5.24	2.71	5.71	2.89	18	33.6	22	14.7
C.I.21E×K201R	5.19	3.19	5.27	3.15	17	5.5	20	38.8
oh7B×K709	5.13	2.82	5.48	2.89	16	25.1	17	68.2
K201R×K712	5.04	2.52	6.10	3.05	21	12.2	18	38.6
K707×K709	4.95	2.63	5.38	3.07	29	27.2	21	45.5
C.I.7×K201R	4.94	2.99	5.83	3.22	26	20.8	12	40.0
K201R×K709	4.87	3.02	4.97	2.81	18	52.7	23	23.3
oh7B×K711[a]	4.80	2.58	4.84	2.92	19	49.0	21	14.4
K201R×K705	4.79	2.68	4.69	2.87	23	43.7	24	32.9
K201R×K711	4.74	2.72	5.29	2.57	26	45.8	13	25.5
38-11×K712	4.74	2.58	5.19	3.15	20	33.3	24	25.5
oh7B×K708	4.69	2.96	5.35	3.13	35	28.3	27	15.4
K201R×K708	4.66	2.65	5.01	2.72	29	4.3	16	31.2
oh78B×K201R	4.66	2.56	5.59	3.18	21	30.4	21	21.5
oh7B×K705	4.66	2.73	4.74	2.62	19	65.1	14	9.9
K4×K201R	4.65	3.09	5.81	3.32	17	51.7	24	34.7
K704×K707	4.64	2.60	5.62	2.68	41	53.7	15	15.2
K4×oh29	4.63	2.73	5.04	2.93	30	31.2	21	27.2
38-11×K707	4.61	2.71	5.14	3.22	32	43.3	18	20.8
38-11×oh78	4.60	2.91	4.91	2.90	14	40.6	18	33.1
oh7B×K707	4.45	2.49	4.99	2.45	35	15.1	24	30.5
K4×K708	4.43	2.43	5.79	2.95	22	46.5	22	50.0
oh7B×K711[a]	4.21	2.78	5.35	2.87	18	43.7	17	20.0
Averages	4.91	2.84	5.35	2.93	686 (total)	36.2	587 (total)	28.6

[a] These crosses identical.

mg. (K4×K708). At 17% moisture, the range was from 6.10 mg. (K201R×K712) to 4.69 mg. (K201R×K705) for females and 3.32 mg. (K4×K201R) to 2.45 mg. (oh7B×K707) for males. The differences between weights of males reared from the 29 hybrids of the same moisture content were not significant; for females the differences were significant at the 5% level.

A comparison of the average weights of moths with short and long developmental periods from seven hybrids selected at random and maintained at 17% moisture is given in table 3. The average weights of all females having a late emergence (long developmental period) was from 0.27 mg. to 1.37 mg. more than for early (short developmental period) females. With the exception of one lot (C.I.21E×K201R), the late emerging males were also the larger. The exception was the result of the inclusion of one or two very light males in this sample. Often it was found that while the average weights of the late emerging adults were higher, the range of weights was greater; particularly was this true for the females. The smallest female (0.70 mg.) was reared on hybrid K705×K707; the heaviest (11.2 mg.) was on K4×oh7B. These data indicate a strong positive relationship between the length of the developmental period and the weight of the adults when the moisture content remained constant.

Length of the developmental period (egg to adult).—Two different measurements were used to secure information relative to the relationship between weight of adult moths reared from different corn selections and the length of the developmental period. These were (1) days from egg to the emergence of the first moth in each variety and (2) average length of developmental stages of all moths emerging from each variety.

The interval from egg to earliest emergence from the 29 hybrids at 14% moisture ranged from 25 days (K4×oh7B) to 32 days (C.I.7×K712) and averaged 28.3 days (Table 2, initial emergence). At 17% moisture, the range was from 22 days (K707×K711) to 29 days (K201R×K712) and averaged 25.3 days. The average length of the developmental period (Table 2, average length of period from egg to adult) ranged from 32.7 days (K707×K709) to 43.8 days (C.I.7×K201R), averaging 39.5 days at 14% moisture. At 17% moisture the range was from 32.1 days (K4×K708) to 39.1 days (oh7B×K706), averaging 34.2 days.

A significant correlation at the 5% level (N=0.386)

Table 2.—Development of the Angoumois grain moth when reared on selected single cross corn hybrids containing varying percentages of moisture. [a]

Hybrids	Percentage of Eggs Hatching			Percentage of Larvae Emerging as Adults		Number of Days to Initial Emergence		Average Period from Egg to Adult (Days)	
	A[b]	B	C	A	B	A	B	A	B
K4×oh7B	92.3	94.8	89.5	50.4	51.5	25	25	39.0	35.3
K707×K711	93.0	88.5	96.8	49.6	45.1	30	22	43.5	32.9
oh78×K706	92.3	92.6	93.5	50.0	55.0	28	27	39.0	39.1
C.I.7×oh7B	83.5	93.6	91.6	62.2	40.5	29	23	40.4	33.8
K711×K712	89.1	96.3	97.1	49.5	48.0	29	27	42.8	36.0
C.I.21E×oh7B	93.6	95.5	94.0	46.7	48.5	28	24	38.1	33.1
C.I.7×K712	94.1	96.1	89.6	54.8	54.7	32	26	41.4	34.2
C.I.7×K711	95.8	93.5	91.1	55.1	52.5	29	26	40.3	36.4
C.I.21E×K201R	95.1	93.0	91.6	49.7	44.6	29	25	42.2	35.8
oh7B×K709	89.3	91.8	96.3	55.1	54.8	27	24	38.7	33.1
K201R×K712	88.0	94.0	90.5	52.2	48.7	27	29	38.9	38.6
K707×K709	91.5	91.6	96.8	48.9	51.0	26	25	32.7	32.7
C.I.7×K201R	91.6	92.1	95.6	55.6	52.6	30	23	43.8	36.3
K201R×K709	88.1	95.8	91.8	58.7	54.7	26	27	41.0	36.7
oh7B×K811[c]	92.6	88.6	94.6	51.2	54.3	26	27	38.5	38.5
K201R×K705	89.6	95.6	97.8	47.2	44.5	31	24	42.8	36.5
K201R×K711	89.8	96.8	95.8	57.5	55.4	26	25	36.0	34.7
38-11×K711	91.3	88.6	94.5	46.5	43.6	30	25	41.1	33.1
oh7B×K708	93.6	91.5	92.6	52.4	50.8	29	23	37.7	33.6
K201R×K708	93.5	94.1	95.3	52.0	54.5	29	25	39.3	34.3
oh7B×K201R	87.8	93.3	96.1	50.2	48.5	29	26	39.9	35.7
oh7B×K705	90.1	86.5	92.8	47.6	49.5	28	26	36.0	38.6
K4×K201R	87.5	92.0	94.0	57.9	49.6	30	26	41.5	38.4
K705×K707	92.6	91.3	93.1	51.4	54.0	29	26	37.8	37.0
K4×oh29	95.0	92.0	94.5	51.7	64.8	26	24	37.8	33.2
38-11×K707	93.3	90.3	92.8	51.2	43.5	29	26	38.9	36.4
38-11×oh7B	93.0	90.6	94.6	42.4	46.5	29	25	40.1	35.7
oh7B×K707	88.3	91.0	92.1	55.4	61.5	27	27	37.1	33.8
K4×K708	92.0	93.5	94.1	53.9	40.9	27	25	37.6	32.1
oh7B×K711[c]	93.3	92.6	91.0	51.0	40.6	27	26	36.5	35.9
Averages	91.4	92.6	93.7	51.9	49.8	28.3 (av.)	25.3 (av.)	39.5	34.2

[a] Each sample infested with 600 eggs.
[b] Indicates moisture content of corn used: A, 14%; B, 17%; C, 21%.
[c] These hybrids identical.

was found between the duration of the immature stages and the weight of the adults reared on different hybrids of 14% moisture. No correlation was found for similar comparisons on different hybrids of 17% moisture.

Fecundity of females reared from the 29 single cross hybrids.—An attempt was made to determine differential responses on the part of the insect to the various corn hosts by measuring the fecundity of females reared on the different hybrids (Table 1, oviposition of moths). The average number of eggs produced from females reared on 14% moisture corn varied from 4.3 to 71.8; on 17% moisture corn from 9.9 to 68.2. The average rate of oviposition per cage ranged from 0.0 to 192.6 eggs per female. The averages were 36.2 eggs per female from corn with 14% moisture and 28.6 eggs per female reared on corn with 17% moisture. It was thought that the wide variations in egg numbers were the result of unnatural oviposition conditions and did not reflect effects of the host hybrids under natural conditions. No significant correlation was detected between oviposition and the weight of adults reared on the hybrid grains at either moisture level.

Larval survival.—Data were secured on the percentage of larvae which emerged as adults from each of 29 single cross hybrids at 14 and 17% moisture (Table 2, percentage of larvae emerging as adults). The survival and emergence at 14% moisture ranged from 42.4% (38-11 ×oh7B) to 62.2% (C.I.7×oh7B); at 17% from 40.5% (C.I.7×oh7B) to 61.5% (oh7B×K707). The actual emergence varied from 226 to 336 adults per sample. The average percentage of larvae emerging as adults was 51.9 and 49.8 at the lower and upper moisture levels, respectively. No significant differences in larval survival in grain from the different hybrids were detected at either moisture level.

Effects of moisture content of the grain on Angoumois grain moth development and behavior.—Weight of adults.—The average mean weights for the females and males from 14% corn were 4.91 and 2.84 mg. respectively (Table 1, weight of moths); for 17% corn, 5.35 and 2.93 mg. The differences in average weights between males reared on the hybrid corn with 14 and 17% moisture were not significant. However, differences in the average weights between females reared at the two moisture levels were significant at the 1% level.

Length of developmental period.—Data in table 2 show that the average number of days from egg to earliest-to-emerge adult were 28.3 at 14% moisture and 25.3 at 17% moisture. Thus the moths from the corn with higher

Table 3.—Comparison of the weight of early and late emerging adult Angoumois grain moths from grain of the same hybrid.[a]

Hybrid	Average Weights (mg.)			
	Females		Males	
	Early	Late	Early	Late
CI.21E×K201R	5.27	6.64	3.15	2.76
K4×oh7B	6.00	6.27	3.10	3.34
CI.7×K201R	5.83	6.99	3.22	3.44
K4×K201R	5.81	6.68	3.32	3.63
oh7B×K705	4.74	5.23	2.62	3.05
K705×K707	5.62	6.54	2.68	2.87
oh7B×K706	5.11	5.79	2.73	3.11

[a] Moisture content, 17%.

moisture content emerged exactly 3 days before the others. Also, the average length of the developmental period was 39.5 days for 14% moisture corn and 34.2 days for 17% moisture corn with a difference of 5.2 days favoring the 17% moisture environment. However no significant correlation was detected between the duration of the immature stages reared on the same hybrid at the two moisture levels.

Fecundity.—Variations in the fecundity of the moths were so great (Table 1, oviposition of moths) that actual differences resulting from moisture could not be determined. It would appear that the moths reared from the grain with 17% moisture, even though they were larger, were less prolific than those reared from corn with 14% moisture.

Hatching of eggs.—Increasing the moisture level of the grain favored an increased hatch of eggs (Table 2, percentage of eggs hatching). On grain with 14% moisture 91.4% of the eggs hatched. At the 17% moisture level the hatch was 92.6% and 93.7% on corn with 21% moisture. The increase in hatch was consistent though not significant.

SUMMARY.—The Angoumois grain moth exhibited variable responses when reared on strains of the same host species (29 single cross corn hybrids) at moisture levels of 14 and 17 per cent. There were no significant differences in larval survival in grain from the different hybrids at either moisture level. The differences in average weights between males reared on the various hybrid grains with 14 and 17% moisture or between males reared from hybrids at the same moisture level were not significant. Differences in the average weights between females reared at the two moisture levels were significant at the 1% level; while between females reared on different hybrid grains with the same moisture content were significant at the 5% level. Increasing the moisture content of the grain from 14 to 17% reduced the average period to initial emergence from all samples by an average of 3 days though no significant correlation was detected between the duration of the immature stages reared on the same hybrid at the two moisture levels. A significant correlation at the 5% level was found between the duration of the immature stages and the weight of the adults reared on the different hybrids with 14% moisture. No correlation was found for similar comparisons on hybrid grains with 17% moisture. A strong positive relationship developed between length of developmental period and the weight of the adult when the moisture content and host strain remained constant. The smallest female weighed 0.7 mg.; the heaviest 11.2 mg. There was no significant correlation between oviposition and the weight of the adults reared on the hybrid grains at either moisture level.

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Microbial Control of Some Lepidopterous Pests of Crucifers[1]

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The most important lepidopterous pests of crucifers in Hawaii are the imported cabbageworm, *Pieris rapae* (L.), and the cabbage webworm, *Hellula undalis* (F.) (Holdaway 1944). Two other Lepidoptera, the diamondback moth, *Plutella maculipennis* (Curt.), and the cabbage looper, *Trichoplusia ni* (Hbn.), are often rather common pests. All four species can be controlled with insecticides, but, when applied to vegetables, most of these insecticides deposit residues which may be deleterious to persons eating them. The problem of residue is especially important on leafy vegetables which cannot be easily washed to remove the poison. In order to overcome this hazard, farmers are usually advised to stop spraying with residual insecticides about 3 to 4 weeks prior to harvest. However, during this period a heavy infestation of insects may occur, and a control measure is definitely required in order to prevent severe losses.

Inasmuch as microorganisms that are infectious to insects generally are harmless to man, the possible use of microorganisms in the control of the above-mentioned four lepidopterous pests of crucifers was investigated.

MATERIALS AND METHODS.—The bacterium, *Bacillus thuringiensis* Berliner, and the granulosis virus, *Bergoldia virulenta* Tanada, were selected for this study. The susceptibility of the imported cabbageworm to both pathogens was tested previously (Tanada 1953a, 1953b). As it was determined also that the virus is specific for the imported cabbageworm, the three species, the cabbage webworm, the cabbage looper, and the diamondback moth, were subjected only to the bacterium

Laboratory tests were conducted in the manner described previously (Tanada 1953b). Each test larva was reared individually in sterile half-pint cardboard containers covered with a half of a sterile petri dish and was allowed to feed on a cruciferous leaf held in a small vial of water. Inoculation was performed preorally by feeding the larvae leaves that had been dipped in a suspension of the pathogen.

Field tests were conducted during 1953 and 1954. The microorganisms were suspended in water and applied as sprays with either a quart hand-sprayer or a 4-gallon knapsack sprayer. The bacterial spray was prepared by suspending a weighed quantity of dried spores in water. The virus spray was prepared by suspending in water the macerated body contents of dead fifth-instar cabbageworms that had died of granulosis. The dry bacterial spores were from 1 to 2 years old and were kept in a tightly stoppered bottle at room temperature. The virus material was also 1 to 2 years old and was stored in a refrigerator. This long storage had no noticeable effect on the virulence of either pathogen when tested in the laboratory.

The plants were thoroughly wetted with spray in all the field tests. The rate of spray application on a per acre basis was not calculated, since in the small plots used, slight variations in plant size, spacing between plants and between rows, speed of application, pressure of the sprayer, etc., would result in incorrect conversions when applied to an acre basis.

In all field experiments, samples of dead larvae were collected and examined under the microscope to determine if their deaths had been caused by the pathogen applied for their control. In nearly all cases, the death of the insect was caused by the applied pathogen.

In the first field test, wheat flour at the rate of 4 per cent by weight was used as a wetting agent. Sprays containing wheat flour tended to peel or flake off the leaves after they became dry, and they thereby lost some of their effectiveness. Hence, a wetting-spreading agent, Triton B-1956,[3] recommended by Dr. E. A. Steinhaus was tested in the laboratory to determine if it had any adverse effect on the virulence of either pathogen. It was found that Triton B-1956, even at a very high concentration of 1:100, had little if any effect on the virulence of the virus. When used with the bacterium, Triton B-1956 at 1:100 was possibly unfavorable to the bacterial spores, but at a lower concentration of 1:400 it had no apparent adverse effect. In the field, Triton B-1956 was used at the rate of 1:800, which gave very good wetting of the leaves.

The field tests for comparing the effects of Triton B-1956 and of wheat flour on the virulence of the bacterium are discussed under the sections dealing with the different insect species.

The field experiments were conducted on the campus of the University of Hawaii in Honolulu, Oahu, and at the experimental farm at Waimanalo, Oahu. In each test, the treatments were completely randomized in each block. Each treated plot consisted of two rows of plants. In general, the data were based on the number of live second- to fifth-instar larvae and pupae present. All pupae were removed from the plants after they were counted. Larvae parasitized by insects were considered as living and were removed from the plants after they were counted. Records were taken, in general, from the same plants throughout each test.

IMPORTED CABBAGEWORM.—Previous laboratory tests had indicated that the imported cabbageworm was highly susceptible to both the granulosis virus, *Bergoldia virulenta*, and the bacterium, *Bacillus thuringiensis* (Tanada 1953a, 1953b). The cabbageworm generally died in 4 to 8 days after feeding on the virus, and 2 to 4 days after feeding on the bacterium. In nature, virus epizootics have been observed occasionally to destroy populations of the cabbageworm.

Field Test I.—The first field test was conducted on a small field of broccoli. The plants had been transplanted into the field about 1 to 2 months before the test was made. Ten rows of plants with approximately 18 plants in each row were divided transversely into two blocks

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[2] I wish to express grateful appreciation to Mr. J. C. Gilbert, Vegetable Crops Department, and Mr. H. S. Waki, farm manager of the Waimanalo Experimental Farm, for maintaining the cruciferous plants; to Dr. George W. Chu, Department of Bacteriology, for performing the autopsy on the rabbits; to Dr. C. G. Thompson, formerly assistant insect pathologist at the University of California at present entomologist with the U.S.D.A., for providing the spores of *Bacillus thuringiensis*.

[3] Manufactured by Rohm & Haas Company, Philadelphia, Pennsylvania.

each, and the treatments were assigned to each block at random.

These treatments consisted of: (1) check, (2) granulosis virus—four macerated larvae per gallon of spray, (3) granulosis virus—eight macerated larvae per gallon, (4) bacterium—0.5 gram of spores per gallon, and (5) bacterium—1.0 gram of spores per gallon. All treatments contained wheat flour, 4% by weight, as a wetting and sticking agent.

Effectiveness of the treatments was based on the number of live second-instar and older larvae, pupae, and parasitized larvae which survived on four plants within each treated plot. The same four plants were used throughout the test. Counts were made 2 days prior to spray application and 2, 6, 9, and 15 days after spray application.

During the course of the study, the average number of eggs and first-instar larvae per four plants in all plots was approximately the same, which indicated that oviposition by the females was fairly uniform throughout the field. The results (Fig. 1) indicate that both pathogens were effective in reducing the population of imported cabbageworm. Treatment with bacterial spores caused a rapid reduction in the cabbageworm population within 2 days after spray application. Some cabbageworms showed signs of bacterial infection within 24 hours. The virus treatment, on the other hand, did not markedly lower the cabbageworm population until about the sixth day after spray application. Larvae with symptoms of virus infection were observed 3 to 4 days after spray application. The periods of lethal infection of the two pathogens, accordingly, were identical to those obtained in the laboratory.

When analyzed statistically, the average number of cabbageworms per four plants in the plots treated with bacteria was markedly below ($P=0.01$) those of the check and the virus-treated plots on the second day after spray application. Six days after spraying, the average number of cabbageworms in both the bacterium- and virus-treated plots was significantly below ($P=0.05$) that of the check plots.

The continual decline in the number of cabbageworms in the check plots after the second day was caused by the decreasing number of butterflies in the field. The reduction in butterfly numbers was apparently caused by: (1) the removal of the pupae from all observation plants, which constituted four-fifths of the total field; (2) a microsporidian, *Perezia mesnili* Paillot, and a braconid, *Apanteles glomeratus* (L.), destroyed a certain percentage of the larvae (Tanada 1955); and (3) there was a low influx of butterflies from breeding areas outside of the experimental plots.

Field Test II.—The second field test was conducted on broccoli plants at Waimanalo. This field was divided into three blocks, and the treatments were randomized in each block. The treatments consisted of: (1) check, (2) granulosis virus—two macerated larvae per gallon of spray, (3) granulosis virus—four macerated larvae per gallon, (4) bacterium—0.25 gram of spores per gallon, (5) bacterium—0.5 gram of spores per gallon. Triton B-1956 at 1:800 was added as a wetter-sticker to all treatments.

About 10 days after the broccoli was transplanted into the field and when the plants were only 3 to 8 inches tall, the cabbageworm population began to increase and cause noticeable damage to the young plants. In anticipation of a rapid build-up of cabbageworms, the first spray was applied with a quart-sprayer, utilizing approximately 1 gallon of spray for each treatment. The number of cabbageworms on 10 plants was recorded for each plot, and the same plants were used throughout the test. Records were taken on the same day but prior to spray application, and 2, 5, 8, 12, 15, 19, 22, 27, and 35 days after the first spray application. A second series of sprays at the rate of 2 gallons per treatment were applied on the sixteenth day.

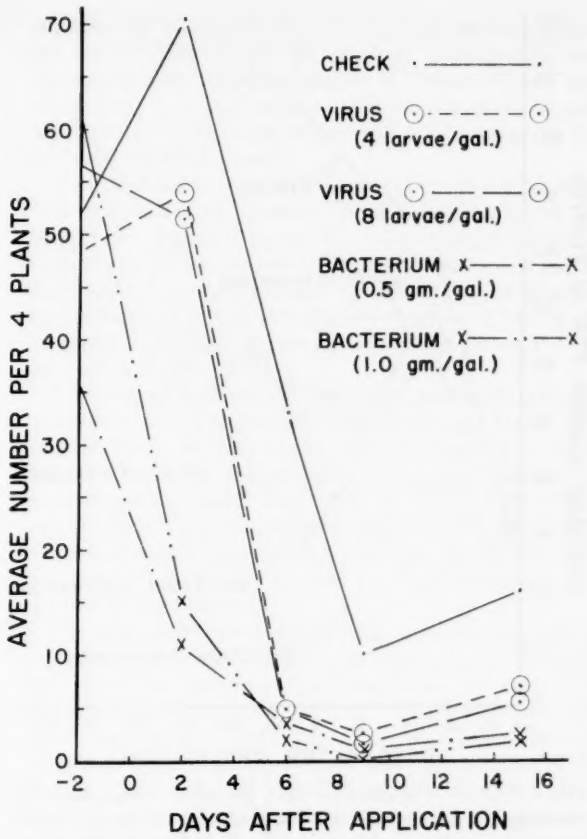

FIG. 1.—Effect of application of a granulosis virus, *Bergoldia virulenta*, and a bacterium, *Bacillus thuringiensis*, on the population of the imported cabbageworm in Field Test I. The microorganisms were applied at zero day.

The cabbageworm population failed to increase as anticipated during the first half of the test; therefore, only the results from the second half of the test, in which there was a great increase, are given in figure 2. The results are somewhat similar to those of the first field test. The bacterium caused a drastic reduction in cabbageworm population in 2 to 3 days. The treatment with virus, however, did not markedly lower the population by the sixth day, as in the first test, mainly because of the rapid increase in cabbageworms. Three days after spray application, the average number of cabbageworms on 10 plants in the plots treated with both concentrations of bacteria was distinctly below ($P=0.01$) those of the check and virus-

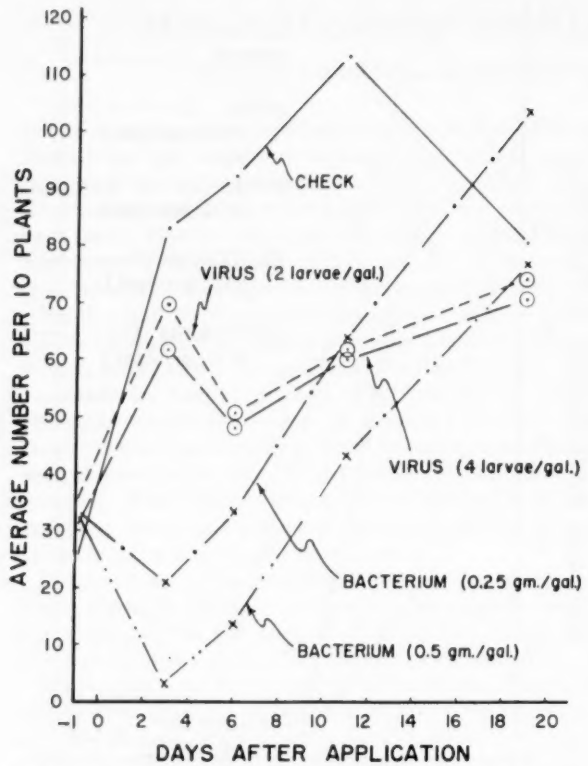

FIG. 2.—Effect of application of a granulosis virus, *Bergoldia virulenta*, and a bacterium, *Bacillus thuringiensis*, on the population of the imported cabbageworm in Field Test II. The microorganisms were applied at zero day.

treated plots, while in the case of the virus-treatments, only the higher virus concentration resulted in a lower ($P=0.05$) number of cabbageworms than that of the check. At 6 and 11 days after spray application, the average number of cabbageworms in both bacterium- and virus-treated plots was much lower ($P=0.01$) than that of the checks. There was little or no difference between the plots sprayed with the two concentrations of the virus. In the bacterium-treated plots, there was significant difference between the two plots treated with the different spore concentrations on the sixth day after spray application; however, both treatments resulted in control of the cabbageworm. The average number of cabbageworms in the plots treated with the higher concentration of the bacterium (0.5 gram per gallon) was also lower ($P=0.05$) than those of both virus treatments. The results indicate that both the virus and the bacterium were effective in controlling the cabbageworm at the lower concentrations tested.

The very rapid increase of cabbageworms resulted in high population counts in the treated plots during the last two recordings made on the eleventh and nineteenth day after spray application. The cabbageworm population in the treated plots during these 2 days, however, was composed mainly of second- and third-instar larvae. A comparison of the number of second- and third-instar larvae with that of the fourth- and fifth-instar larvae and pupae in the treated and check plots during the last two recordings is given in table 1. This comparison indicates that even at this late period the treatments were effective in controlling the older instars, which cause most of the plant damage.

Field Test III.—In the third field test, conducted on cabbage plants at Waimanalo, no virus but only the bacterial treatments were applied. These bacterial treatments were the same as those in Field Test II. Approximately 4 gallons of spray were applied to each treatment.

The field was divided into four blocks with the treatments assigned at random in each block. The cabbageworm population was recorded from 20 plants in each treated plot, and counts were made on the same plants throughout the test. Records were taken on the same day but prior to spray application, and at 3, 6, and 9 days after application.

The results are given in figure 3. Prior to spray application, the average cabbageworm population was not significantly different between the treated and check plots; but 3 days after treatment, the plots treated with 0.25 gram spores per gallon had an average of 4.5 larvae per 20 plants, and those treated with 0.5 gram of spores per gallon had an average of 1.8 larvae per 20 plants as compared to an average of 55 larvae per 20 plants in the check plots. The average number of cabbageworms in the bacterium-treated plots was distinctly lower ($P=0.01$) than those of the check plots up to 9 days after spray application. Treatments with 0.5 gram of bacterial spores per gallon significantly reduced ($P=0.05$) the number of cabbageworms below that of plots treated with 0.25 gram of spores per gallon during the third and ninth day after spray application. However, the latter treatment was also effective in controlling the cabbageworm.

DIAMONDBACK MOTH.—*Laboratory Tests.*—The first of three laboratory tests on the pathogenicity of *B. thuringiensis* for the diamondback moth was conducted with 16 field-collected larvae, 8 of which were held as a check, and the other 8 fed bacterial spores. Two larvae were placed in each container, thus both the check and bacterium-treated lots had four containers with two larvae each. One larva was lost from both the check and the bacterium-treated lots during the test. The seven check larvae completed their development and trans-

Table 1.—Comparison between the average number of young individuals[a] and that of old individuals[b] of the imported cabbageworm in the treated and check plots on the eleventh and nineteenth day after spray application.[c]

TREATMENTS	INDIVIDUALS ON			
	Eleventh Day		Nineteenth Day	
	Young	Old	Young	Old
Granulosis virus (2 dead larvae per gallon)	10.3	0.3	26.3	7.0
Granulosis virus (4 dead larvae per gallon)	11.0	0	26.3	6.3
Bacterium (0.25 gm. per gallon)	9.7	0	52.3	10.7
Bacterium (0.5 gm. per gallon)	6.0	0	34.0	14.3
Check	33.0	28.3	25.7	27.0

[a] Second- and third-instar larvae.
[b] Fourth- and fifth-instar larvae and pupae.
[c] Each figure represents the average number of cabbageworms per 10 plants.

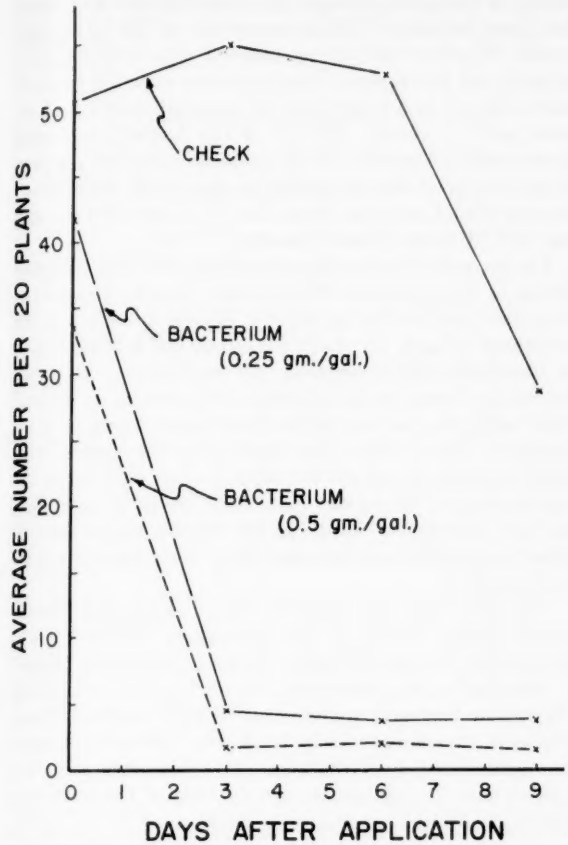

FIG. 3.—Effect of application of a bacterium, *Bacillus thuringiensis*, on the population of the imported cabbageworm in Field Test III.

formed into adults, while all seven that were fed spores died from bacterial infection.

In the second laboratory test, the larvae, which were also field-collected, were divided and treated as follows: 5 check larvae fed untreated foliage, 10 check larvae fed foliage dipped in blood-albumin suspension, and 15 larvae fed foliage dipped in bacterial spores dispersed in aqueous blood-albumin suspension. Eleven of the larvae that were fed spores died from bacterial infection, while the remaining four and all larvae in both checks matured to adults.

The third laboratory test was conducted with fourth- and fifth-instar larvae that had been reared in the laboratory. There were 10 check larvae fed untreated foliage, 10 check larvae fed foliage dipped in blood-albumin suspension, and 20 larvae fed foliage dipped in bacterial spores dispersed in aqueous blood-albumin suspension. All 20 larvae which were fed spores died from bacterial infection within 4 days, with most of them dying on the second day. All larvae in both checks matured to adults. These results indicate that larvae of the diamondback moth are fairly susceptible to *B. thuringiensis*, and when infected die in 1 to 4 days as in the case of the imported cabbageworm.

Field Test I.—The first field test, conducted on broccoli at Waimanalo, had two objectives: (1) to determine whether the diamondback moth and the cabbage looper can be controlled in the field with *B. thuringiensis*, and (2) to compare the effectiveness of Triton B-1956 and wheat flour as wetter-stickers. The results of the experiments with the cabbage looper will be discussed in the section under that insect.

The treatments were as follows: (1) check—4% wheat flour suspension, (2) check—Triton B-1956 at 1:800, (3) bacterium—1 gram of spores in a gallon of 4% wheat flour suspension, (4) bacterium—2 grams of spores in a gallon of 4% wheat flour suspension, (5) bacterium—1 gram of spores in a gallon of Triton B-1956 solution at 1:800, (6) bacterium—2 grams of spores in a gallon of Triton B-1956 solution at 1:800.

The broccoli field was divided into three blocks, and the treatments were randomized throughout each block. The data are based on the average number of second- to fifth-instar larvae and pupae per four plants in each treatment. A pretreatment count was made on October 20, 1953, and the first spray was applied the following day. Post-treatment counts were made on October 23, 26, 29, and November 2, 9, 12, 17, 20, and 24. A second spray was applied on November 10.

The population of diamondback moth in the check plots slowly increased and reached a peak in 8 to 12 days, then subsided somewhat and reached a second much higher peak at the time of harvest, 34 days after the first spray application (Table 2). The population in the bacterium-treated plots did not increase as rapidly as that in the checks. On the fifth day (October 26) after the first spray application, the plots treated with 2 grams of spores per gallon of diluted Triton B-1956 had a much lower ($P=0.01$) average number of diamondback moth than the check plots; the average number in all other bacterial treatments except that with 1 gram of spores in a gallon of wheat-flour suspension was lower ($P=0.05$) than those of the checks. On the eighth day (October 29) after the first spray application, the average number of diamondback moth in all the bacterium-treated plots was distinctly lower than those of the checks. From the twelfth (November 2) to the nineteenth day (November 9), the difference between the populations of the bacterium-treated plots and those of the check plots became less evident.

Following the seventh day (November 17) after the second spray application and up to the fourteenth day (November 24), the populations in all the bacterium-treated plots were at least significantly lower than those of the check plots. Throughout the tests, plots treated with Triton B-1956 as the wetter-sticker had lower populations than comparable plots treated with wheat flour, but the differences were significant only once, on November 17 (7 days after the second spray application). Hence, Triton B-1956 had no adverse effect on *B. thuringiensis* spores. Although the population of the plots treated with 2 grams of bacterial spores per gallon was lower than that of the comparable plots treated with 1 gram of spores per gallon, there was significant difference ($P=0.05$) only once, on October 29 (8 days after the first spray application). Both bacterial spore concentrations, especially with Triton B-1956 as the wetter-sticker, effected control of the diamondback moth.

Field Test II.—The second field test was conducted to-

gether with Field Test III on the imported cabbageworm. The test with the diamondback moth, however, extended over a longer period because its population continued to increase until the cabbages were harvested.

The treatments were check, bacterium at 0.25 gram of spores per gallon, and at 0.5 gram of spores per gallon. Triton B-1956 was added to all treatments at 1:800. Approximately 4 gallons of spray were applied on March 30 and again on April 9.

The data were based on the number of second- to fifth-instar larvae and pupae per 10 plants in each treatment, and the same plants were used for counts throughout the test. Population counts were made on April 2, 5, 8, 12, 15 and 20. The population of diamondback moth in the check plots increased gradually and reached a peak on April 5, six days after the first spray application; then, after subsiding for a short period following the second spray application, it increased sharply in numbers up to the end of the test (Fig. 4).

From the third day after spray application, the populations of both bacterium-treated plots were markedly lower ($P=0.01$) than that of the check plots. The populations of the two bacterium-treated plots were significantly different from each other at the 5% level throughout most of the test period.

At the conclusion of the study, nearly all of the cabbages in the check plots were severely damaged by larvae of the diamondback moth, and approximately 20 per cent of them were unmarketable. Some of the cabbages in the plots treated with bacterium at 0.25 gram of spores per gallon were moderately damaged, but fewer than 5 per cent were unmarketable. A few plants that were sprayed with 0.5 gram of spores per gallon were moderately damaged, but nearly all of them were marketable. The results indicate that the diamondback moth can be controlled by *B. thuringiensis* when applied at the rate of 0.5 gram of spores per gallon. At the rate of 0.25 gram of spores, control may not be adequate.

CABBAGE LOOPER.—*Laboratory Tests.*—The susceptibility of the cabbage looper to *B. thuringiensis* was tested five times because of the inconsistency of the laboratory results. The first test was conducted with field-collected larvae in all five instars. Twelve larvae were fed broccoli leaves dipped in a suspension of bacterial spores, and six were used as checks. Eleven of the bacterium-treated larvae died in 2 to 4 days from bacterial infection, and one larva developed into an adult. In the check, four larvae became adults, one was parasitized by a tachinid fly, and one died from an unknown cause.

The second test was also conducted with field-collected larvae in their third to fifth instars. Twenty-five larvae were used and treated as follows: (1) check—4 larvae fed untreated foliage, (2) check—5 larvae fed foliage dipped in blood-albumin suspension, (3) bacterium—16 larvae fed foliage dipped in an aqueous suspension of spores and blood albumin. Larvae fed bacteria began dying from infection in 1 to 6 days after feeding on the spores, with most of them dying on the second day. Fifteen of the bacterium-treated larvae died from bacterial infection, and one matured to adult. In the checks, six larvae matured to adults, and the other three were parasitized by tachinid flies.

The third test was conducted with third- and fourth-instar larvae reared in the laboratory. There were 5 larvae fed untreated foliage, 10 larvae fed foliage dipped in blood-albumin suspension, and 15 larvae fed foliage dipped in bacterial spores dispersed in aqueous blood-albumin suspension. Only 2 of the bacterium-treated larvae died from bacterial infection, 3 died from unknown causes, and 10 emerged as adults. One of the untreated larvae died from an unknown cause, and 4 emerged as adults; all 10 larvae that were fed blood albumin matured to adults.

The fourth and fifth tests were conducted with laboratory-reared fourth-instar larvae. The treatments and the number of larvae used in the tests were the same as in the third test, except that wheat flour was used as the wetting agent in the fifth test. In the fourth test, 10 of the

Table 2.—Effect of treatment[a] with *Bacillus thuringiensis* on the population of the diamondback moth in Field Test I.

Treatments	Average No. per Four Plants		Average Square Root of Number per Four Plants[b]							
	Oct. 20 Pre-treatment	Oct. 23	Oct. 26	Oct. 29	Nov. 2	Nov. 9 Pre-treatment	Nov. 12	Nov. 17	Nov. 20	Nov. 24
Bacterium—1 gm./gal. +wheat flour	1	4.3	2.63	4.14	5.31	3.83	2.46	4.08	5.41	7.97
Bacterium—2 gm./gal. +wheat flour	2.7	4.0	2.15	3.20	4.33	2.93	2.32	2.96	3.66	6.59
Bacterium—1 gm./gal. +Triton B-1956	5.3	4.7	2.02	3.78	4.35	2.64	2.00	1.57	3.31	5.52
Bacterium—2 gm./gal. +Triton B-1956	3.3	1.0	1.48	1.74	3.02	2.79	1.87	1.10	2.09	4.49
Check—wheat flour	1	3.3	4.10	6.31	6.38	4.62	3.13	8.68	10.41	14.23
Check—Triton B-1956	3	7.7	4.02	6.71	7.11	3.79	4.04	7.56	9.92	16.83
L.S.D. at 5% level			1.69	1.88	2.44	1.75	1.64	1.96	2.29	4.10
at 1% level			2.40	2.68	3.47			2.79	3.26	5.82

[a] Wheat flour at 4% by weight and Triton B-1956 at 1:800 were used as wetter-stickers. Sprays were applied on October 21 and November 10.

[b] For analysis of variance, data with many numbers below 10 were transformed to $\sqrt{X+0.5}$, (higher numbers to $\sqrt{X}$) in which X was the observed number of individuals (Snedecor 1946).

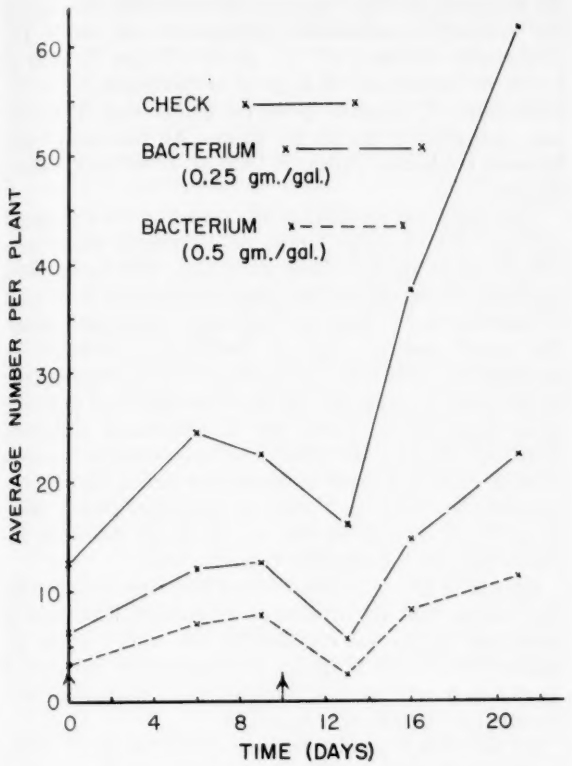

FIG. 4.—Effect of application of a bacterium, *Bacillus thuringiensis*, on the population of the diamondback moth in Field Test II. Sprays applied on zero and ninth days, and indicated by arrows on the base line.

bacterium-treated larvae died from bacterial infection and five matured to adults. All check larvae reached adulthood.

In the fifth test, nine of the bacterium-treated larvae died from bacterial infection, three from unknown causes, and three emerged as adults. Only one of the larvae that were fed wheat flour died from an unknown cause, and the remaining larvae in both check groups became adults.

The laboratory results indicate that certain individuals of the cabbage looper are resistant to *B. thuringiensis*. Field-collected larvae appeared to be more susceptible to the bacterium than laboratory-reared ones, but this apparent difference should be subjected to further tests.

Field Test.—Only one field test was conducted on the control of the cabbage looper with *B. thuringiensis*. This test was made in the same field of broccoli at Waimanalo as was used in Field Test I for the diamondback moth. The plot arrangement, treatments, and the recording of the data were the same for both of these species. This test also had the same two objectives: (1) to test the control of the insect with *B. thuringiensis*, and (2) to compare Triton B-1956 and wheat flour as wetter-stickers.

Although the test was started on October 20, 1953, the study on the cabbage looper was confined to the second half of the test, beginning November 9, because of the insufficient numbers during the first half. On November 9 the population of the cabbage looper was recorded, and the treatments were applied the following day. Approximately 3 gallons of spray were applied to each plot. Posttreatment records were obtained on November 12, 17, 20, and 24.

The results are given in table 3. Although many dead larvae were observed in the bacterium-treated plots on the second day (November 12) after spraying, the difference between the populations of the bacterium-treated plots and those of the check plots was not significant. From the seventh (November 17) to the fourteenth day (November 24) after spray application, the plots treated with bacterial spores at the rate of 2 grams of spores in a gallon of Triton B-1956 at 1:800 had a significantly lower population than those of the check plots, with a possible exception on the tenth day (November 20). Plots sprayed with 2 grams of spores suspended in a gallon of 4% wheat flour had lower populations ($P=0.05$) than that of the check sprayed with Triton B-1956 but not with that of the check sprayed with wheat flour. Triton B-1956 apparently had no adverse effect on the virulence of *B. thuringiensis* spores.

The results of the field test confirmed those of the laboratory tests: the cabbage looper was partially resistant to *B. thuringiensis*. Successful control of the looper apparently may be obtained with a spray containing 2 grams of bacterial spores per gallon when there is a moderate infestation of cabbage loopers, but higher spore

Table 3.—Effect of treatment[a] with *Bacillus thuringiensis* on the population of the cabbage looper.

Treatments	Average No. per Four Plants		Average Square Root of Number per Four Plants[b]		
	Nov. 9 Pretreatment	Nov. 12	Nov. 17	Nov. 20	Nov. 24
Bacterium—1 gm./gal.+wheat flour	17.33	11.67	2.68	2.04	2.84
Bacterium—2 gm./gal.+wheat flour	15.33	8.67	1.97	2.09	3.28
Bacterium—1 gm./gal.+Triton B-1956	17.33	7.67	2.27	2.32	3.81
Bacterium—2 gm./gal.+Triton B-1956	14.00	4.67	1.35	1.68	2.04
Check—wheat flour	14.33	13.00	4.31	4.13	4.21
Check—Triton B-1956	16.00	15.67	5.07	4.96	4.17
L.S.D. at 5% level			2.50	2.52	1.44
at 1% level			3.55		2.05

[a] Wheat flour at 4% by weight and Triton B-1956 at 1:800 were used as wetter-stickers. Treatments were applied on November 10.
[b] Same as for table 2.

concentrations may be necessary with very high infestations.

CABBAGE WEBWORM.—*Laboratory Tests.*—The first laboratory test was conducted with laboratory-reared cabbage webworms in their third to fifth instars. The larvae were exposed to the following treatments: (1) 10 check larvae fed untreated foliage, (2) 10 check larvae fed foliage dipped in wheat-flour suspension, (3) 20 larvae fed foliage dipped in *B. thuringiensis* spores dispersed in aqueous wheat-flour suspension. Unfortunately, all the webworms were infected with Microsporidia prior to the tests.

Nineteen of the bacterium-treated larvae died within 1 to 4 days with bacterial and microsporidian infections, and the other larva died on the fifth day from a microsporidian infection. Five of the larvae in the first check and six in the second check died with microsporidian infection after 12 days. The remaining larvae of both checks matured to adults.

Although the briefness of the period of lethal infection indicated that *B. thuringiensis* was mainly responsible for the deaths of the bacterium-treated larvae, the susceptibility of the webworm may also have been associated with the presence of the microsporidian. Subsequently, only stocks of webworms free from microsporidian infection were used.

In the second test, the check fed untreated foliage had five larvae, the check fed wheat-flour suspension had four larvae, and the bacterium-treated group had nine larvae. The larvae were in their third to fifth instars. Seven of the bacterium-treated larvae died from bacterial infection, one from an unknown cause, and one matured to adulthood. One of the check larvae fed wheat flour died from an unknown cause. The remaining three larvae and all five larvae of the check fed untreated foliage matured to adults.

The third laboratory test was conducted with 9 larvae in the check fed untreated foliage, 10 larvae in the check fed wheat-flour suspension, and 20 larvae fed bacterial spores. All larvae in both checks matured to adults. Thirteen of the bacterium-treated larvae died from bacterial infection and seven from unknown causes. These results suggest that the cabbage webworm may be partially resistant to *B. thuringiensis*.

Field Test I.—Field tests on the control of the cabbage webworm with *B. thuringiensis* were conducted on plantings of pak choi, *Brassica chinensis* L., at Waimanalo. In the first test the field was divided into three blocks and the treatments randomized throughout each block. The treatments consisted of: (1) check—Triton B-1956 at 1:800, (2) bacterium—0.25 gram of spores per gallon, (3) bacterium—0.5 gram of spores per gallon, and (4) bacterium—1.0 gram of spores per gallon. All the sprays with bacteria contained Triton B-1956 at 1:800 as a wetter-sticker.

The webworm population was based on the number of second- to fifth-instar larvae on 15 plants which were pulled out at random from each plot. The sprays were applied on June 15, and the population counts were made 3 (June 18) and 7 (June 22) days after spray application. The results indicate that *B. thuringiensis* reduced the population of webworm in the treated plots significantly below that of the check (Table 4). On the third day after spray application, there was a significant difference ($P = 0.05$) between the number of webworms in the plots treated with 0.25 gram of spores per gallon and that in the plots treated with 1 gram of spores per gallon. However, after 7 days there was no significant difference between these two bacterium-treated plots.

Field Test II.—The second field test was similar to the first except that the treatment containing 0.25 gram of spores per gallon was replaced by one with 2 grams per gallon. Three series of sprays were applied to the plots on August 6, 9, and 19. The populations of webworms were recorded on August 11, 16, and 24.

All the plots treated with bacteria had lower ($P = 0.05$) numbers of webworms than that of the check plots, except on August 16, when the plot sprayed with 0.5 gram of spores per gallon had a higher number than the check (Table 4). There was significant difference ($P = 0.05$) between the number in the plots treated with 0.5 gram of spores per gallon and that in the plots treated with 2 grams per gallon on August 11 and 16 but not on August 24.

The results of the two field tests indicate that treatment with bacteria was effective in keeping down the webworm population for 2 to 5 days after spray application, but lost its effectiveness in about 7 days. This may be caused by the continuous infestation of the plant by webworms and by the rapid growth of the plant which develops new leaves that have not been exposed to the spray. Thus, for webworm control, a number of spray applications at short intervals may be required.

Inasmuch as webworms attack the growing points of

Table 4.—Effect of treatment with *Bacillus thuringiensis* on the population of the cabbage webworm.[a]

Treatments	Field Test I[b]		Field Test II[c]		
	June 18	June 22	Aug. 11	Aug. 16	Aug. 24
Bacterium—0.25 gm./gal.	16.33	33.00	—	—	—
0.5 gm./gal.	12.00	37.33	27.00	93.00	103.67
1.0 gm./gal.	6.67	32.00	18.67	55.67	44.33
2.0 gm./gal.	—	—	12.67	31.67	36.67
Check	28.00	57.00	44.67	71.67	194.67
L.S.D. at 5% level	8.91	15.61	14.04	29.61	74.44
at 1% level	13.50	23.65	21.28	44.85	112.77

[a] Figures represent average number of larvae per 15 plants.
[b] Treatments were applied June 15.
[c] Treatments were applied August 6, 9, and 19.

cruciferous plants a relatively few webworms per plant can cause serious economic damage. Although plants treated with 0.5 gram of spores per gallon had a small webworm population, they suffered some damage. A concentration of at least 1 to 2 grams of spores per gallon is apparently needed to control the webworm.

PATHOGENICITY TO MAMMALS.—Berliner (1915), who described *B. thuringiensis*, reported that white mice when fed this bacterium showed no signs of disease. Steinhaus (1951) demonstrated that this bacterium was not infectious to rabbits when inoculated intradermally, subcutaneously, intraperitoneally, or preorally. Moreover, a human volunteer who drank a culture of the bacterium showed no ill after effects.

Although no one has yet found an insect virus that is pathogenic to mammals, it was felt desirable to test the possibility of pathogenicity of the granulosis virus of the imported cabbageworm to mammals. The pathogenicity test was performed on four unmated rabbits, variety New Zealand White, which were about 4 months old. Two of the rabbits were males and two females. The virus inoculum was prepared from remains of cabbageworms that had died of granulosis. These remains had been kept 2 years in the refrigerator but were still highly infectious to the imported cabbageworm. About 0.15 ml. of the white virus sediment at the bottom of a vial was pipetted into 50 ml. of sterile distilled water.

One male and one female rabbit were each fed 1 ml. of the virus inoculum with a sterile glass pipette on the first day. The dosage was increased to 3 ml. after the first day and continued for 7 days. The male and female check rabbits were fed comparable amounts of sterile distilled water.

The rabbits were weighed before the test, and subsequently every 3 to 4 days. At the start of the test they weighed from 5½ to almost 6½ pounds. On the seventh day, both virus-treated rabbits had lost 3 ounces, while the check female rabbit lost 1 ounce, and the check male lost no weight. On the eleventh day, the virus-treated female rabbit had regained all its lost weight and the virus-treated male had regained 1 ounce but was still 2 ounces lighter than at the start of the test. The check male rabbit had lost 1 ounce and the female had gained 4 ounces since the start of the test. Aside from the slight differences in weight, there was no apparent difference between the virus-treated and check rabbits. None of the rabbits showed signs of diarrhea or other symptoms of illness.

After 29 days the rabbits were again fed virus in order to determine whether there would be an indication of susceptibility when fed fresh virus. The virus inoculum was prepared by suspending the macerated body contents of 10 fourth- and fifth-instar cabbageworms that had recently died of granulosis in 30 ml. of sterile distilled water. In this trial, the rabbits that had been used previously as checks were fed the virus and the former virus-treated ones became the checks. This conversion was decided upon because there was a possibility that the virus-treated rabbits may have acquired an immunity from the first virus feeding.

Each test rabbit was fed once with 3 ml. of the virus inoculum, and the check rabbits were each fed 3 ml. of sterile distilled water. At the end of 9 days the rabbits were weighed, and then killed for autopsy. During this 9-day period, the virus-treated male rabbit failed to gain any weight, the virus-treated female gained 7 ounces, the check male gained 2 ounces, and the check female gained 5 ounces.

The autopsy of all four rabbits failed to reveal any gross pathology in their internal organs. These rabbits were eaten by human volunteers, none of whom experienced any ill effects.

DISCUSSION.—During recent years, microorganisms have been successfully applied for the control of some important insect pests. Most of these insects are forest pests, but others, such as the alfalfa caterpillar, *Colias philodice eurytheme* Boisd., and the Japanese beetle, *Popillia japonica* Newm., have also been effectively controlled with infectious microorganisms. Thus far, very few attempts have been made to control insect pests on leafy vegetables by use of infectious microorganisms. Inasmuch as toxic residue on leafy vegetables is a major problem with the application of most insecticides, the use of insect pathogens that are nonpathogenic to mammals is certainly worth investigating.

The bacterium, *Bacillus thuringiensis*, and the granulosis virus, *Bergoldia virulenta*, are apparently nonpathogenic to mammals. They have been applied to cruciferous plants that were consumed by human volunteers without any ill effects.

Of four important pests of crucifers in Hawaii, the imported cabbageworm was most easily controlled with the bacterium and the granulosis virus. The virus was effective in a spray prepared by suspending in a gallon of water the macerated body contents of two fifth-instar cabbageworms that had died of granulosis. The bacterium controlled the cabbageworm at a very low concentration of 0.25 gram of spores per gallon (*ca.* 1 ounce per 100 gallons). It reduced the cabbageworm population much more quickly than did the virus, and in this respect was superior to the virus.

Kelsey (1955), in an unpublished report, stated that in his first test a spray prepared by suspending the body contents of two granulosis-killed cabbageworms in a pint of water was effective in controlling the imported cabbageworm when applied immediately after preparation. In his second test, the virus suspension was held for 6½ hours before application, and none of the sprayed cabbageworm became infected. He concluded that the virus was only effective when used immediately after preparation. His results are surprising in view of the fact that the writer prepared his inoculum from material that had been kept under refrigeration for 1 to 2 years. Moreover, aqueous virus suspensions held in refrigeration for several days were still infectious.

The application of *B. thuringiensis* for the control of the other three pests, the diamondback moth, the cabbage looper, and the cabbage webworm, was not as effective as in the case of the imported cabbageworm. The larvae of the diamondback moth appeared to be slightly more resistant to the bacterium than larvae of the cabbageworm. Although a spray containing 0.25 gram of spores per gallon significantly reduced the population of diamondback moth below that of the check plot, a concentration of at least 0.5 gram of spores per gallon (*ca.* 2 ounces per 100 gallons) may be required for effective control.

Both the cabbage looper and the cabbage webworm

were much more resistant to *B. thuringiensis* than the other two species discussed above. For both pests, a concentration of 1 to 2 grams of bacterial spores per gallon (*ca.* ¼ to ½ pound per 100 gallons) was effective for moderate infestations. When these two species occur in very large numbers, the bacterium may have to be applied at a higher concentration or may even be economically ineffective since laboratory studies have indicated that certain individuals are resistant to the bacterium.

There may be some question as to the availability of either pathogen. No commercial source is known in America, but spores of *B. thuringiensis* have been sold in Europe. This bacterium, as pointed out by Steinhaus (1951), grows well on ordinary nutrient agar, and can easily be produced in large quantities in a short time. In the case of insect viruses, Steinhaus & Thompson (1949), and Thompson & Steinhaus (1950), have suggested that large quantities of virus can be produced by (1) rearing large numbers of the host larvae in the insectary and then infecting them, or (2) by gathering naturally-infected larvae from the fields and holding them in the insectary until they died. They adopted the second method for their study with the polyhedrosis virus of the alfalfa caterpillar. These two methods can also be applied to obtain quantities of the granulosis virus of the imported cabbageworm.

In recent years there have been numerous examples of the adverse effect of insecticides on insect parasites and predators, resulting in a subsequent higher host density or an abnormal increase of other arthropod pests. Steinhaus (1954) has thoroughly discussed the effect of diseases on the density-dependent control factors, such as insect parasites and predators. He has presented examples in which parasites and disease function against each other, others in which they work in concert; in some instances the disease enhances the activity of the parasites, and in others the parasites favor the disease by acting as agents of transmission or dissemination of the pathogens.

In the present study, the pathogenic microorganisms applied to crucifers for the control of four insects had no marked effect on insect parasites or predators, especially those attacking hosts other than the four insects studied. High infestation of aphids developed on some plants, but frequently they were destroyed by coccinellids, lacewing flies, and hymenopterous parasites.

When the bacterium and virus infect young cabbageworms, the insect parasites developing within them are generally unable to complete their development. However, when older hosts are infected by these microorganisms the insect parasites sometimes complete their development. In the field, larvae of *Apanteles glomeratus* were observed emerging from a cabbageworm which showed marked symptoms of granulosis. These *Apanteles* larvae were held in a vial in the laboratory where they pupated and emerged as adults. Another example was observed in the laboratory, where a field-collected fifth-instar cabbageworm had been infected by granulosis, and, even though it showed marked symptoms of granulosis, it gave rise to *A. glomeratus* larvae which pupated and emerged as adults. *A. glomeratus*, however, failed to emerge from younger cabbageworms infected with granulosis.

On the other hand, Holdaway & Lucas (1941) observed that where the "wilt" disease occurred among the imported cabbageworms, parasitism by *Apanteles glomeratus* was nil, while the maximum parasitism of 95.7 per cent was found in a place where the disease was not recorded. This "wilt" disease was probably the granulosis virus disease (Tanada 1953b). They also observed that *A. glomeratus* died when the host was affected by "wilt," but apparently the mortality was less in the case of the tachinid parasite, *Frontina archippivora* Will.

Pathogenic microorganisms can be used for the control of some of the important lepidopterous pests of crucifers in Hawaii, but there is still the problem of controlling the major piercing-sucking pests, such as the cabbage aphid, *Brevicoryne brassicae* (L.), the harlequin bug, *Murgantia histrionica* (Hahn), and the onion thrips, *Thrips tabaci* Lind. The writer is not aware of any microorganism that can be applied effectively against any of these insects, and until suitable pathogens are discovered these pests must be controlled with insecticides or insect parasites and predators. One of the problems that needs to be investigated in the future is to determine whether *B. thuringiensis* and the granulosis virus can be safely combined with a contact insecticide and possibly a fungicide also. The contact insecticide should be one that effectively controls the piercing-sucking insects and leaves no toxic residue on the plants.

SUMMARY.—Four important lepidopterous pests of crucifers in Hawaii are the imported cabbageworm, *Pieris rapae*, the cabbage webworm, *Hellula undalis*, the diamondback moth, *Plutella maculipennis*, and the cabbage looper, *Trichoplusia ni*. The imported cabbageworm was effectively controlled in the field by a granulosis virus, *Bergoldia virulenta* Tanada, and a bacterium, *Bacillus thuringiensis* Berliner. The virus was effective in a spray prepared by suspending in a gallon of water two macerated fifth-instar cabbageworms that had died of granulosis. The bacterium was effective at 0.25 gram of bacterial spores per gallon of spray (*ca.* 1 ounce per 100 gallons). The bacterium offers more promise than the virus in the control of the cabbageworm because it kills the cabbageworm in a shorter period—2 to 4 days as compared to 4 to 8 days for the virus.

The larva of the diamondback moth appeared slightly more resistant to *B. thuringiensis* than the imported cabbageworm. A bacterial spray of 0.5 gram of spores per gallon (*ca.* 2 ounces per 100 gallons) was required to control this species. Both the cabbage webworm and the cabbage looper were much more resistant to *B. thuringiensis* than the above two species, and approximately 1 to 2 grams of bacterial spores per gallon of water (*ca.* ¼ to ½ pounds per 100 gallons) were required for their control. At very high infestations of the latter two species, the bacterium may have to be applied at a much higher concentration or may even be economically ineffective because of the presence of some resistant individuals.

Triton B-1956, when added at a concentration of 1:800 to the virus or the bacterial spray, had no apparent adverse effect on the virulence of either pathogen. It was a better wetter-sticker than wheat flour, and sprays containing it appeared more effective than those with wheat flour.

Both the granulosis virus and the bacterium appear non-pathogenic to mammals and plants. They offer

promise in the control of the above pests on leafy vegetables, especially in cases where the use of insecticides results in a problem of poisonous residues.

The virus and bacterium exhibited no marked adverse effect on insect parasites and predators.

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Insecticidal Seed Treatment for Control of the Thief Ant[1]

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The thief ant, *Solenopsis molesta* (Say), is the most injurious pest of planted sorghum seeds in south-central Kansas when weather and soil conditions are unfavorable for rapid germination of seed (Bryson 1941). Ants are so abundant and active at times that they seriously damage or destroy all seed planted in a field. Corn is also attacked under similar conditions.

Ant damage may be recognized by the presence of kernels with germs hollowed out, the endosperm particles strewn along the drill row, empty seed coats and the presence of the tiny yellowish-red ants crawling around slowly in the soil. Injury is more severe when milo and other sorghums are planted in early spring or summer when the temperature and soil moisture content are too low to insure rapid germination of seed. Similar injury may result when milos and other sorghums are planted in early summer when soil temperature and soil moisture are insufficient to stimulate germination.

Since this species does not build a mound, its presence and abundance are not readily detected without careful examination of the soil in the drill row. Observations indicated that galleries and nests, containing the queen and brood, were constructed near the soil surface in spring and early summer when the soil was moist and cool but were placed deeper when the surface became hot and dry. Because of these habits, the ant cannot be controlled by measures recommended for the control of mound-building species.

Hayes (1920) made a biological study of this species and reported instances when thousands of acres of sorghums required replanting because of seed damage. He also tested the repellent effect that kerosene, turpentine, carbolic acid, creosote, and coal tar had upon it, but found none of these satisfactory control. Chemicals showing promise as a protectant against ant attacks, injured the germination of the seed and were difficult to apply.

Laude & Swanson (1933) stated that no satisfactory seed treatment was known which would protect seed from ant injury. They recommended thorough seed bed preparation to hasten germination and planting about May 10 in southern Kansas to reduce ant injury. Smith *et al.* (1943) listed *Solenopsis molesta* a destructive species in sorghum production and suggested tilling the soil just prior to planting in warm, moist soil to minimize injury. Bryson (1954) noted the regular occurrence of the ant problem and conducted preliminary chemical seed treatment tests with "Mergamma" and lindane with unsatisfactory results.

MATERIALS AND METHODS.[3]—Studies were begun January 1954, using certified seed of three varieties of sorghums, namely, Atlas sorgo, Ellis sorgo and Westland milo. Insecticides and insecticide-fungicide formulations were applied at different rates to determine the effect of each upon germination, subsequent plant growth, adherence of the chemicals to the seed, and the effectiveness of promising ones against ant attack. The insecticides[4] used were wettable powders of 75% aldrin, 50% heptachlor, and 25% lindane. Insecticide-fungicide combinations

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[3] Mergamma (gamma isomer of BHC, 40%; other isomers of BHC, 2%; phenyl mercuric urea, 1.93%; inert ingredients, 56.07%) by Chipman Chemical Co., Bound Brook, N. J.

[4] Chemicals supplied as follows: aldrin by Shell Chemical Corp., Denver, Colo.; heptachlor by the Velsicol Corp., Chicago, Ill.; lindane and Seed Guard (16.5% lindane, 50% N-trichloromethylmercapto-4-cyclohexane-1, 2-dicarboxamide and methyl cellulose) by California Spray Chemical Corp., Richmond, Calif.; Panogen PL-1 (solution containing 36.8% lindane [95% grade] and 0.5% methyl mercury dicyandiamide) and Panogen PA-2 (solution containing 24.4% hexachloro-hexahydro-dimethano-naphthalene [aldrin equivalent to 25.6%] and 0.4% methyl mercury dicyandiamide by Panogen Inc., Ringwood, Ill.

used included Seed Guard, a commercial wettable powder formulation, and liquid Panogen PL-1, and Panogen PA-2.

To determine the effect of each chemical upon the various sorghum varieties, a given quantity of seed was weighed and placed in a glass fruit jar. Various amounts of each insecticide and insecticide-fungicide formulation were carefully weighed or measured and added to jars containing the weighed seed on a basis of fluid or avoirdupois ounces per 100 pounds of seed. Mixing was accomplished by placing six jars containing the treated samples on the arms of a mechanical, motor-driven rotary mixer, rotated at a spead of five revolutions per minute for 5 minutes. The stock samples of treated seeds and one untreated sample were then placed in individual cotton sacks and stored in a dry attic room to simulate farm storage conditions. The summer temperatures in this room reached a maximum of 118° F. on several occasions.

Periodically 110 seeds were removed from each sample and sent to the State Seed Laboratory, Topeka, Kan., for official germination tests. Identical samples were removed simultaneously and planted in insecticide-free silt loam soil in metal flats placed on tables out of doors. The seeds were evenly spaced, planted about ½ inch deep in rows and watered when necessary, with the same quantity of water. Soil used in flats was a silt loam, taken from a field which never had been treated with insecticides.

Seeds removed from stock samples for official germination tests and for planting in flats were selected immediately following treatment, 1½ months and 4 months after treatment in order to determine the effect of storage upon the germination of treated seed. Only the germination data for seed planted in the flats immediately after treatment are shown in table 1. One sample was germinated in the official germinator after 9 months storage but not planted in flats out of doors.

Counts were taken daily as soon as the first seedling appeared above the soil surface to determine the rate at which each sample germinated. When the number of seedlings remained constant for at least 3 days, it was assumed that all viable seeds had germinated and produced seedlings with sufficient vigor to appear above the surface. The rate of emergence was calculated according to the method employed by Lange *et al.* (1949). To compare different treatments with the untreated check, a 95% confidence interval was fixed for each check using the binomial distribution table (Snedecor 1950). The treatment data falling within these computed limits were considered satisfactory when compared with their respective checks. Emergence data and germination percentages for each variety and treatment are presented in table 1.

Tests were conducted to determine the amount of insecticide which could be retained on seed coats of three varieties of sorghum and produce a uniform coverage. The varieties used were Westland milo, Ellis sorgo and Atlas sorgo, while the chemicals applied were wettable powders of heptachlor, Seed Guard, lindane and aldrin.

Table 1.—Insecticides applied and their effect upon seed germination and rate of emergence of sorghum seedlings.

Chemical and Concentration	Ounces per 100 Lbs. of Seed	Seeds[a] Planted in Flats Immediately After Treatment						Per Cent of Germination in Standard Tests (After Treatment)											
		Mean Emergence Period in Days			Per Cent Germination			Immediately			1½ Months			4 Months			9 Months		
		W	A	E	W	A	E	W	A	E	W	A	E	W	A	E	W	A	E
Aldrin 75%, W. P.	2.5	6.3	6.5	6.4	54	86	77	74	95	90	72	93	89	72	91	84	74	85	79
	4.5	6.3	6.4	6.4	57	76	73	56	90	77	60	88	86	66	93	76	64	84	71
	5.5	6.3	6.6	6.4	56	66	79	65	86	86	59	89	81	54	85	76	68	83	83
Panogen, PA-2 (fluid)	6.0	6.3	6.4	6.4	53	80	75	77	87	87	69	91	82	70	83	87	48	89	88
	7.0	6.3	6.4	6.3	56	81	86	79	96	92	67	92	84	70	85	86	57	79	83
	8.0	6.4	6.4	6.4	56	72	81	74	85	88	72	81	85	50	82	82	47	79	83
Lindane 25, W. P.	3.0	9.8	6.5	6.3	44	72	74	50	85	82	53	83	68	60	79	81	41	87	69
	4.0	9.8	6.5	7.0	41	62	52	62	86	78	56	81	82	46	80	73	47	78	78
	5.0	9.8	6.5	8.3	29	63	54	51	78	72	45	84	63	32	82	72	45	80	65
Panogen, PL-1 (fluid)	2.0	9.9	7.3	8.6	45	66	67	28	22	71	59	65	57	41	74	70	45	77	61
	2.5	10.0	7.4	9.7	43	62	66	8	34	41	32	57	65	35	76	71	42	62	70
	3.5	10.8	8.0	9.8	36	65	62	4	4	12	13	6	72	33	54	62	38	42	67
Seed Guard	2.7	6.0	5.9	5.9	67	93	92	66	92	92	75	93	91	73	91	85	63	91	92
Heptachlor 50%, W. P.	4.0	6.3	6.5	6.4	49	68	75	54	87	86	64	82	86	59	86	85	59	86	78
	5.0	7.0	6.5	6.4	32	66	72	51	86	91	62	90	82	52	85	74	57	80	76
	6.0	7.7	6.5	6.5	35	69	73	46	87	85	55	92	81	52	88	82	68	80	80
Untreated	0	6.4	6.5	6.5	55	63	72	60	87	82	62	88	88	42	86	82	68	89	78
95% confidence interval limit	—	—	—	—	45 to 65	53 to 72	62 to 81	50 to 70	79 to 93	73 to 89	52 to 72	80 to 94	80 to 94	32 to 52	78 to 92	73 to 89			

[a] Varieties are indicated as follows: W, Westland; A, Atlas; E, Ellis.

Table 2.—**Mean weight of insecticides in ounces avoirdupois retained on Westland milo per 100 pounds of seed.**[a]

Insecticide	Concentration in Ounces per 100 Pounds of Seed					
	2	4	8	16	32	Average All Concentrations
Seed Guard	1.84	3.82	7.80	15.78	30.34	11.92
Aldrin	1.76	3.76	6.24	13.04	13.50	7.67
Lindane	1.60	3.14	5.42	12.78	13.14	7.22
Heptachlor	1.36	3.02	5.42	11.70	13.02	6.90
Average	1.64	3.44	6.22	13.32	17.52	8.43

[a] Moisture 12.8%.

Concentration rates used ranged from 2 to 32 ounces of the formulated material per 100 pounds of seed. Each treatment was replicated five times. The difference in weight before and after application gave the amount of insecticide adhered to the seed. The percentage of moisture in the seed sample was determined with a Steinlite moisture tester. The results were analyzed statistically and the data tabulated in table 2. Since the results for each variety were so nearly alike, only those for Westland milo are given.

Kafir-ant colonies were taken from the field, established and maintained in the field insectary. These were exposed to treated and untreated seeds to determine the effectiveness of the seed treatment as a control measure. Observations of the ants in artificial ant nests indicated that the ants could not break the seed coats of dry hard seeds under normal storage conditions but destroyed the seeds when planted in soil with moisture content sufficient to soften the seed coat but which did not stimulate germination (Fig. 1).

Considerable difficulty was experienced in an attempt to colonize ants under artificial laboratory conditions. Fifteen earthen crocks, 1 foot in diameter and 7 inches deep, were filled with 6 inches of black loam soil. A few fragments of flat rocks and some coarse gravel were placed in the middle layer of soil to furnish a place under which the queen and brood were placed by the ants. Eight queens, 200 workers and a quantity of brood were introduced into each crock. Vaseline was used to coat the edge and portion of the crock extending above the soil surface to serve as a barrier to prevent the ants from migrating. The soil was maintained moist and friable almost equivalent to good tilth. The queen and workers soon established their brood under the rock. The crocks containing the colonies were kept in an underground cave as described by McColloch (1917).

After starving the ants a few days, Westland milo seeds, which had been soaked in water and honey were offered the ants. After 2 days the ants began to feed on the

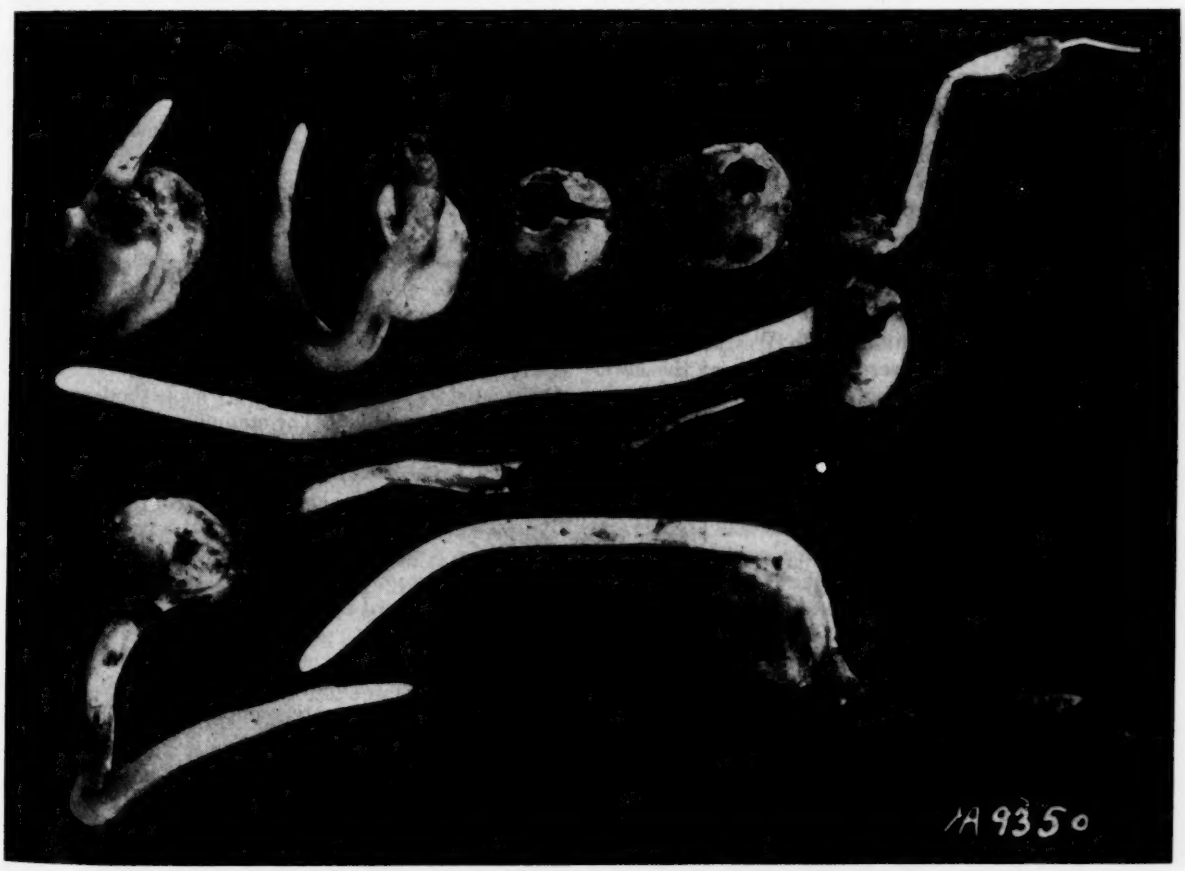

PLATE I.—Thief ant injury to untreated sorghum seed (×6).

seeds. This process of feeding was continued for 1 week, after which water soaked seeds without honey were given. After the ants had become accustomed to feeding upon the untreated seeds, 25 seeds of one treatment were placed on a piece of wire screen, covered with moist soil and buried in the culture crock. Four such sets of different treatments were placed in a culture crock which was not disturbed for 2 weeks. The culture was then examined and the injured seeds counted. The results are recorded in table 3.

RESULTS.—Table 1 shows that in germination tests in flats, Westland milo treated with three different rates of lindane and PL-1 retarded the emergence period a little more than 3 days. The two highest dosages of heptachlor retarded germination slightly and reduced germination except that germination was satisfactory at the 4-ounce level. Seed treated with Seed Guard emerged more uniformly and germinated more rapidly than that treated with other insecticides. Aldrin and PA-2 caused little, if any, injury but neither stimulated germination nor emergence of seedlings as did Seed Guard.

Atlas sorgo treated with PL-1 and lindane at the higher levels retarded germination and, to some extent emergence, while Seed Guard hastened germination. PA-2, aldrin and heptachlor were slightly above the satisfactory level so far as emergence was concerned.

Ellis sorgo samples, treated with 4 or 5 ounces of lindane, showed a significant reduction in the production of seedlings, accompanied by an appreciable delay in germination. Panogen PA-2 applied at 7 fluid ounces, aldrin at all rates, and Seed Guard showed no apparent stimulation to emergence of seedlings. Heptachlor and aldrin gave similar results. Official germination tests varied somewhat from the results obtained when like samples were planted in flats. The difference is explainable because data from the germination tests include counts of seeds which sprouted and died while the germination counts in flats were taken when the plumule emerged above the soil surface so that seeds which germinated and produced seedlings too weak to appear above the surface were not counted.

In standard germination tests with Westland milo, all treatments with lindane were satisfactory at the lower confidence interval limit but PL-1 seriously reduced germination and was more pronounced at higher rates. Heptachlor was satisfactory at the lower level. PA-2 and aldrin did not affect germination and Seed Guard was above the average.

Ellis sorgo treated with the highest rate of lindane and all three dosages of PL-1 reduced markedly the viability of seed. Germination was above the check with several formulations. Data on Ellis sorgo also indicated that the injurious effect of lindane and PL-1, evident immediately after treatment, continued in subsequent tests but did not increase in severity.

Atlas sorgo was generally affected similarly to Ellis, when treated with the same chemicals. The highest dosage of aldrin and the median of PA-2 were above the satisfactory limit when compared with check. Lindane showed an injurious effect upon germination of treated seeds germinated immediately following treatment but the injury did not increase in subsequent test periods. PL-1 continued injurious at succeeding test periods.

Table 3.—Effect of seed treatments on damage by the thief ant.

INSECTICIDE	OUNCES PER 100 LBS. SEED	NO. OF SEEDS[a]			PER CENT OF SEEDS DAMAGED BY ANTS
		Sown	Damaged by ants	Damaged by other causes	
Aldrin	4.5	25	0	2.3	0
Panogen PA-2	7.0 fl. oz.	25	0	1.7	0
Lindane	4.0	25	0	3.0	0
Panogen PL-1	2.8 fl. oz.	25	0	1.7	0
Seed Guard	2.7	25	0	1.3	0
Heptachlor	5.0	25	0	2.7	0
Check	Untreated	25	12.7	2.7	50.7

[a] Average of three replications.

Since the Westland milo used had low vitality, as indicated by weak germination in the check, injury was greater in those applications where chemicals tended to injure the seed. Less injury occurred where high germinating seed was used.

Seed Guard was retained in larger amounts than were any of the other formulations, the differentiation being more significant at the 8-ounce or greater concentration. The amount of Seed Guard retained increased in direct proportion to the amount applied, but there was a reduction in the retention rate at the 32-ounce level. For other treatments, the rate of retention generally decreased from 8 to 16 ounces and showed only a slight increase going from 16 to 32 ounces. Seed Guard gave the most uniform coating. Heptachlor retained less in comparison with other insecticides but this was because the 50% heptachlor wettable powder used was not so finely ground as were Seed Guard and the 75 % aldrin. The finely ground insecticides did not flake off readily when the seed was handled.

Results presented in table 3 show that all treatments gave complete protection of the seeds under the conditions of the tests. An examination of the damaged seed in the check showed about 50% completely hollowed, leaving only the outer coat. The nature of the protection which the insecticides gave the seeds was not determined. Further observations are needed to determine whether the ants were repelled or killed. Ant colonies exposed to the treated seeds dwindled rapidly while those exposed to untreated seeds did not. The minimum dosage required to control the ant was not determined.

SUMMARY.—Wettable powders of 75% aldrin, 25% lindane, 50% heptachlor, Seed Guard and solutions of Panogen with lindane, PL-1, and Panogen with aldrin, PA-2 were applied to seeds of Westland milo, Ellis sorgo and Atlas sorgo at three concentrations, with the exception of Seed Guard applied at the rate recommended on the container.

The stock samples of seeds were treated with the chemicals at the beginning of the experiment and stored in cloth sacks in a dry attic room to simulate farm storage of seed.

One hundred ten seeds were removed from each treated sample immediately, 1½, 4 and 9 months after treatment. These were sent to the State Seed Laboratory where 100 seeds were germinated in an official standard seed germinator. Similar 100-seed samples were planted immediately, 1½ and 4 months after treatment, in flats containing

loam soil; only the results on samples planted immediately following treatment are given.

Aldrin wettable powder and PA-2 solution did not injure germination or retard growth of seedlings. Lindane wettable powder and Panogen PL-1 reduced germination and emergence of seedlings. Seed Guard and PA-2 stimulated the rate of germination and subsequent growth of seedlings. Heptachlor at the highest concentration injured germination on Westland milo.

Injury evident following treatment did not increase in intensity during 9 months in storage.

Wettable powders of heptachlor, aldrin, lindane, and Seed Guard were applied to sorghum seed samples at the rate of 2, 4, 8, 16, and 32 ounces of the chemicals per 100 pounds of seed. The amounts of these chemicals which adhered to seed coats were determined. At all rates Seed Guard was retained in higher amounts than any of the other insecticides with the differentiation in the amounts retained evident only beyond the application of 8 ounces per 100 pounds of seed. The amounts of the other chemicals retained generally decreased from 8 to 16 ounces and showed only a slight increase from the 16 to 32 ounce rate. Aldrin wettable powder coated the seed more uniformly than lindane or heptachlor wettable powder owing to the fineness to which it was ground. The heptachlor wettable powder used was coarsely ground and did not adhere so well as the finely ground powders or the Seed Guard which contained a methyl cellulose sticker.

Thief ant injury was prevented by treating Westland milo with aldrin, Panogen PA-2, lindane, Panogen PL-1, Seed Guard, and heptachlor at the rate 4.5, 7.0, 4.0, 2.8, 2.7 and 5.0 ounces per 100 pounds, respectively. The untreated check showed more than 50% of the seeds destroyed by the ants.

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Control of Onion Thrips and its Tolerance to Certain Chlorinated Hydrocarbons[1]

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During the 1955 season, experiments were conducted to evaluate new insecticides and to test the effectiveness of currently recommended insecticides for commercial control of onion thrips, *Thrips tabaci*, Lind., at the Winter Garden Experiment Station and at the Lower Rio Grande Valley Experiment Station. Particular attention was focused on the suspected tolerance of onion thrips to some chlorinated hydrocarbon insecticides.

Economical control of the onion thrips was not successful until DDT was introduced. Hibbs & Ewart (1946) found that 3% DDT gave the best control in 1945; but, that DDT was most effective in combination with sulphur in 1946. Satisfactory control was being obtained in 1946 with DDT in the Valley (Richardson & Wene 1952). Fife *et al.* (1948) reported excellent results with DDT in controlling onion thrips on cotton in 1947. DDT continued to give effective control of thrips on onions in 1947 and 1948 but combinations with other new organic materials were superior (Wene 1948). A review of literature by Richardson & Wene (1952) showed that workers in various states had obtained good control of the thrips on onions with DDT. However, the results of tests in the Lower Rio Grande Valley in 1950 indicated a decline in control with DDT (Richardson & Wene 1952).

The latter paper also reported some of the first trials showing heptachlor, dieldrin, aldrin and toxaphene giving good control of the onion thrips in the Winter Garden area and in the Lower Rio Grande Valley in 1950 and 1951. Other workers (Mayeux & Wene 1950, Wene & White 1951, and Chapman 1952) also reported that dieldrin, heptachlor and aldrin gave effective control of onion thrips in the Lower Rio Grande Valley. Sloan *et al.* (1951) and Merrill (1952) reported good control of the onion thrips with these materials in other states. Heptachlor and dieldrin were still giving outstanding results in 1952 in the Winter Garden area; the effectiveness of aldrin and toxaphene seemed to have decreased from that of previous years (Richardson 1953). In 1953, dieldrin and heptachlor continued to control the onion thrips very effectively but aldrin and toxaphene showed a decline for

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the second year in succession (Richardson 1954). It appeared in 1954 that the onion thrips were becoming tolerant to some of the chlorinated hydrocarbons. Although good control was still obtained in the Lower Rio Grande Valley with dieldrin and toxaphene, decided tolerance was exhibited to dieldrin, heptachlor, aldrin and toxaphene in the Winter Garden area. In addition to the usual ground sprays, airplane distribution also resulted in tolerance to these materials when applied alone; but, satisfactory results were obtained when parathion was used with heptachlor, dieldrin and aldrin (Richardson & Wene 1955). Results of the 1954–55 experiments confirm that the onion thrips continues to have tolerance for these materials, when used alone, in the Winter Garden area; and, for the first time, that the condition exists in the Lower Rio Grande Valley.

PROCEDURE.—Two organic insecticide evaluation experiments were conducted in a field adjoining the Winter Garden Experiment Station. Records were taken from blocks in Zavala County on which sprays had been applied by airplane. These blocks, varying in size, were treated at the rate of 4 gallons per acre. The onions were planted in double rows with 38 inch centers. Experimental plots treated with ground equipment were 1/109 acre in size and were replicated four times. The rate applied in each test was 23 gallons per acre. The onions were planted in single rows spaced 16 inches apart.

One dust and two spray experiments were conducted in the Lower Rio Grande Valley for the control of the onion thrips. The dust treatments were applied with rotary hand dusters at 20 pounds per acre. The two spray applications were made with a 3-gallon garden sprayer adapted in such a manner that two nozzles directed towards each row of onions applied 5 gallons per acre. The sprayer pressure was kept at 40 pounds. The onions were planted in single rows spaced 36 inches apart.

Records for all insecticide experiments by ground application at the Winter Garden and the Valley Stations were taken by counting the onion thrips on 10 plants per plot at various intervals after a single application. Records from the airplane applications were taken from 10 plants in each of 4 locations. The percentage reduction in infestation was based on the thrips population in the untreated check in all experiments except where the airplane was used. In this test, the initial infestation at the time of application was used because it was impractical to leave check plots.

RESULTS.—Results of tests performed in the Winter Garden area are shown in table 1.

Test 1.—Perthane, BHC plus DDT, and Chlorthion gave fair control of thrips on onions 1 day after application. These materials were still effective 5 days after application but perthane had the least residual effect. The other materials were decidedly ineffective.

Test 2.—Methyl parathion, dieldrin plus parathion, malathion, and parathion gave fair control of the onion thrips 1 day after application. The dieldrin plus parathion mixture was the only material giving even moderate commercial control 6 days after application. None were effective 9 days after application.

Airplane Test.—In the blocks which received treatments by airplane, parathion was the only material giving fair commercial control 1 day after application. On the fourth day, malathion, dieldrin plus malathion, and parathion were all giving fair to good control of the onion thrips. The dieldrin-malathion mixture and parathion had lost all residual effect 9 days after application; malathion was still very effective 12 days after application.

Table 1.—Control of the onion thrips with organic sprays in the Winter Garden area during 1955.

Pounds of Toxicant per Acre in 23 Gallons of Water		Days After Application			
		1	4 to 6	8 to 9	12
		Per Cent Reduction			
	Test 1				
0.5	heptachlor	53.6	0.0	33.6	
0.28	dieldrin	43.0	2.4	13.2	
0.5	aldrin	24.5	0.0	9.8	
0.2	endrin	33.8	0.0	0.0	
0.4	endrin	41.8	15.3	16.6	
2.0	toxaphene	21.5	11.4	0.0	
0.5	Perthane	77.2	61.2	23.0	
0.5	Chlorthion	70.9	68.2	27.2	
0.3	BHC plus 0.5 DDT	75.1	75.3	35.7	
	Test 2				
0.25	parathion[a]	70.7	56.7	33.3	
0.17	parathion[b]	66.2	56.2	43.8	
0.63	malathion	72.9	43.3	29.0	
0.25	methyl parathion	81.2	60.6	50.2	
0.5	Pyrazoxon	44.4	47.0	9.8	
0.5	Diazinon	64.7	37.8	25.6	
0.19	dieldrin plus 0.25 parathion[b]	78.2	70.6	37.0	
	Test 3[c]				
0.19	dieldrin plus 0.31 malathion	63.0	83.9	0.0	0.0
0.38	parathion	71.8	75.5	0.0	0.0
0.63	malathion	56.7	90.4	72.5	86.3

[a] Two pounds of actual parathion per gallon.
[b] Four pounds of actual parathion per gallon.
[c] Applied by airplane at 4 gallons per acre.

Results of all tests performed in the Lower Rio Grande Valley are shown in table 2.

Test 1.—All dust treatments, except 2.5% heptachlor, gave good commercial control of the onion thrips 1 day after application. Since these onions were harvested soon afterwards, no residual records were possible.

Test 2.—In the first spray experiment, mixtures of malathion plus heptachlor, and malathion plus dieldrin, and malathion, alone, were effective in controlling the onion thrips 1 day after application. Malathion had lost its residual effect and the mixtures were not very effective 7 days after treatment. None of the chlorinated hydrocarbons gave good control alone.

Test 3.—Good control was obtained from malathion plus Perthane, and 1 pound malathion, alone, in the second spray test. Seven days later, the mixture of malathion plus Perthane, 1 pound malathion, Diazinon, and Hercules AC 528 were showing good residual control. The latter two materials were apparently slow in action.

DISCUSSION.—The necessity of continual screening of new insecticides and testing the effectiveness of currently recommended insecticides in the same areas is emphasized in the results from experiments for the control of the onion thrips in the Winter Garden area and the Lower

Table 2.—Control of the onion thrips with organic insecticides in the Lower Rio Grande Valley during 1955.

Formulation		Days After Application: 1	7
		Per Cent Reduction	
	Test 1—Dusts[a]		
2.5%	heptachlor	67	
2.5%	heptachlor plus 1% parathion	99	
5%	heptachlor	79	
5%	heptachlor plus 1% parathion	89	
1%	parathion	86	
4%	Diazinon	97	
	Test 2—Sprays[b]		
0.5	malathion plus 0.19 dieldrin	81	62
0.5	malathion plus 0.38 dieldrin	78	70
0.38	dieldrin	49	10
0.75	dieldrin	60	47
0.5	malathion plus 0.25 heptachlor	78	63
0.5	malathion plus 0.5 heptachlor	83	66
0.5	heptachlor	54	21
2.0	toxaphene	37	47
0.5	malathion	78	40
	Test 3—Sprays[b]		
0.5	malathion plus 1.0 perthane	92	92
0.5	malathion	44	8
1.0	malathion	80	92
0.5	Diazinon	68	83
0.5	Hercules AC 528[c]	44	83

[a] Dusts were applied at 20 pounds per acre.
[b] Toxicant applied per acre (lbs.) in 5 gallons of water.
[c] 2,3-*p*-Dioxanedithiol S,S-bis(*O,O*-diethyl phosphorodithioate).

Rio Grande Valley. Combinations of chlorinated hydrocarbons and phosphates with chlorinated hydrocarbons seemed to give continued effective commercial control of the onion thrips. When used alone, heptachlor, dieldrin, aldrin and toxaphene have failed to effect commercial control 2 years in succession. Although the results from the Lower Rio Grande Valley did not indicate a tolerance by the onion thrips in 1954, the results from the Valley in 1955 agree very well with the tolerance exhibited in the Winter Garden area in 1954 (Richardson & Wene 1955) and repeated in 1955. The phosphate compounds have continued their effectiveness and exhibit no loss of control of the onion thrips. The possibility of tolerance to the organic insecticides will be of great interest in the future in the Winter Garden area and the Lower Rio Grande Valley.

SUMMARY.—In the Winter Garden area, combinations of BHC plus DDT, and dieldrin plus parathion gave good control of the onion thrips. Chlorthion, methyl parathion, malathion, and parathion were effective 1 day after application. Chlorthion and parathion retained fair control 5 days later. Perthane was the only chlorinated hydrocarbon exhibiting any commercial control of the onion thrips when used alone. Heptachlor, dieldrin, aldrin, endrin, toxaphene, Pyrazoxon and Diazinon were of no commercial value in the control of the onion thrips.

In the Lower Rio Grande Valley, commercial control of the onion thrips was obtained with combinations of heptachlor plus parathion dust, malathion plus dieldrin spray, malathion plus heptachlor spray, and malathion plus Perthane spray. Dusts of Diazinon, parathion and heptachlor were effective 1 day after application. Sprays of malathion, Diazinon and Hercules AC 528 were effective for 7 days. No control was obtained with dieldrin, heptachlor or toxaphene sprays.

The tolerance of the onion thrips to several chlorinated hydrocarbons apparently indicates that it is becoming resistant to dieldrin, heptachlor and toxaphene in the Winter Garden area and the Lower Rio Grande Valley.

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Annotated List of Insects Found in or near Roots of Cultivated Crucifers in New Brunswick[1]

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In New Brunswick early cabbage and early cauliflower suffer severe damage annually from root maggots. In the past decade the losses have become so great that many growers have discontinued growing these early crops. The 1947 records showed that losses due to root maggots were approximately 29 per cent of the total crop. This has increased steadily and in 1951 the loss recorded was over 45 per cent.

Most of the losses may be attributed to the cabbage maggot, *Hylemya brassicae* (Bouché), which has been increasing in numbers steadily since 1937. In 1947 a preliminary survey indicated the need for information on the economic status of this root maggot, as well as related species, attacking cultivated crucifers. A study was initiated at Maugerville that year and was continued for 5 years. This is an annotated list of the insects encountered during the 5-year study of *H. brassicae* and its association with cultivated cabbages, cauliflowers, turnips, and swedes. The ecological succession of the maggots recorded and the interrelations of the species complex were not determined.

Twenty-four genera, of two orders and 14 families, were represented in the collections. The Diptera are arranged systematically according to Curran (1934) and the Coleoptera according to Leng *et al.* (1920). The maggots were identified when possible from the key by Brooks (1951). Adult Diptera were identified by Mr. A. R. Brooks, Saskatoon, and Mr. G. E. Shewell, Ottawa, and the Coleoptera by Mr. W. J. Brown, Ottawa, all of the Entomology Division.

Methods.—In making collections, the crown of the plant and the soil around it were examined. All eggs found were removed by hand. The plant was then pulled and the maggots on the root hairs and in the root were collected. The soil around the plant was sifted for pupae to a depth of 6 inches and within 4 inches from the center of the root. The eggs were reared in the insectary by the plaster of paris technique of Searls (1928). The maggots were reared *en masse* throughout the period, some being reared individually in 1951 and 1952.

Daily collections were made from early cabbage and early cauliflower plots until after the peak of population of *H. brassicae*, usually the first week of June. From then until the crop was harvested in the latter part of July, the collections were made every other day. After that, the collections were made weekly. Collections from late cabbages, late cauliflowers, turnips, and swedes began the first week of July, but since these crops did not harbor the heavy populations of the early crops the collections were made only twice weekly.

DIPTERA

Bibionidae

Bibio xanthopus Wied. Adults emerged in late July of each year from pupae taken from cabbage and cauliflower plants.

Dolichopidae

Dolichopus bifractus Lw. This species was common on cabbage plants in June and adults began emerging the first of July each year.

Syrphidae

Paragopsis strigatus (Fall.). Larvae usually appeared about the middle of June and were present in moderate numbers until the first week of July. No specimens were taken after July 7.

Drosophilidae

Scaptomyza graminum (Fall.). Larvae were abundant in collections each year about the first of July and adults began emerging from caged material during the last week of July or the first week of August. Friend (1927) reported this species as a new raspberry pest attacking the fruit; normally it is a leaf miner.

Chloropidae

Oscinella neocoxendix Sabr. Generally this species did not appear in the collections until after the peak of population of *H brassicae*. It was taken in collections during July and the first part of August each year.

Oscinella soror (Macq.). This species was always found in association with *O. neocoxendix* and during the same period.

Helomyzidae

Helomyza serrata (L.). From a late-fall field collection from Laurentian swede turnips, several mature maggots and pupae were obtained. In the spring one adult emerged on May 17, 1947.

Muscidae

Coenosia tigrina (F.). Larvae appeared in numbers in the collections at the peak of population of *H. brassicae* each year. In the insectary adults emerged during late June and early July. Hille Ris Lambers (1932) and Mayne (1933) reported that this species was predacious on adults of *Pegomya hyoscyami* Panz., and Perron (1952) observed it attacking adults of the onion maggot, *H. antiqua* (Mg.).

Fannia canicularis (L.). Larvae were common each year throughout June and July on cabbage. No specimens were taken after August 20.

Fannia fuscula Fall. Larvae were present at the time of the initial infestation of *H. brassicae* in May of each year and field captures of adults around cabbage and cauliflower plants were common during mid June.

Fannia glaucescens (Zett.). Larvae were common in collections from both early cabbages and early cauliflowers in June, 1951. Reared specimens emerged during July.

Hylemya brassicae (Bouché). This is the most prevalent and injurious of the root-inhabiting species of maggots in New Brunswick. During the 5 years of the study this species comprised 80 to 90 per cent of the total maggot population. Adults were present in the field from the middle of May to the middle of November.

Hylemya cilicrura (Rond.) (=*H. cana* (Macq.)). Larvae were found in collections from cabbages from June to October. Adults were present in the field from the middle of June to the first of October. This species is the second most abundant species of the root-inhabiting insects attacking crucifers in New Brunswick. Collections indicate that it prefers cabbage and cauliflowers but it has been taken also from turnips and swedes.

Hylemya depressa Stein. Maggots were generally present in

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field collections from the first of July to late September. Adults emerged from reared material during the latter part of July and the first week of August.

Hylemya fugax (Mg.). Eggs were taken in the field near cabbages during the first week of July. They were never present in very large numbers. Miles (1927) reported this species damaging cabbages.

Hylemya nidicola (Ald.). Larvae did not appear in the field collections until the latter part of July. The adult was taken in the field as early as June 24. From overwintering cages the earliest emergence record was July 11, in 1947. Smith (1939) reports that this species is one of the native parasites of grasshoppers.

Hylemya liturata (Mg.) (=*H. trichodactyla* (Rond.)). Small numbers of larvae were present each year, in field collections from cabbages, cauliflowers, turnips, and swedes. Adults began emerging about the second week in June, and field captures were made as late as August 21.

Leucophora sp. Larvae were taken only during June. Adults began emerging from reared material during mid July of each year.

Muscina assimilis (Fall.). Larvae were taken each year in field collections from both cabbages and cauliflowers. The earliest record was on July 2, 1951, and the latest on October 22 of the same year. It was always very abundant during July and August.

Muscina stabulans (Fall.). In 1947 larvae were abundant only on roots of all four crucifers that harbored an extremely heavy population of *H. brassicae*. It was taken occasionally in 1948, 1949, 1950, and 1951. The first record of adult emergence was August 8, with sporadic emergence until September 16. This species has been recorded as a parasite of *Pissodes strobi* (Peck) (MacAloney 1930) and of *Macronoctua onusta* Grt. (Breakey 1929). Downes (1941) considered the larvae as scavengers. Jablonowski (1930) observed this species attacking half-opened buds of iris, and Isaev (1931) found it attacking healthy onions.

Myospila meditabunda (F.). Larvae were abundant in the field collections from early cabbages and early cauliflowers during the first part of July each year.

Keilin (1917) states that this species is undoubtedly carnivorous, feeding on saprophagous larvae as well as on larvae of certain small anthomyiids. No sign of this carnivorous habit was detected.

Paregle cinerella (Fall.). Larvae were taken near cabbages in field collections during June each year in very small numbers. In 1950 adults were taken on July 4, from overwintering cages placed over the remains of cabbages after the heads had been harvested.

Paregle radicum (L.). Larvae and pupae were present in field collections from cabbages and cauliflowers only during June. Swarms of Diptera were observed along the headlands and near cabbages and cauliflower along the margins of the fields on July 12, 13, and 14 in 1951. Closer observation revealed that they were alighting in numbers on daisy, *Chrysanthemum leucanthemum* L., and fall dandelion, *Leontodon autumnalis* L., more particularly on daisy, in the flowers of which they appeared to be standing almost on their heads. So intent were they on feeding that they were easily captured. *H. liturata* (Mg.) was present in association with *P. radicum*.

Pegomya ruficeps Stein. Adults were present during June and a few larvae were taken in collections from cabbages in late July and early August of each year.

Scopeuma stercoraria (L.). From the mass rearings of the field collections adults of this species emerged during July in 1947 and in 1950.

METOPIIDAE

Pollenia rudis (F.). Larvae were taken in association with *H. brassicae* from July to the end of August each year. Essig (1942, pp. 806–807) states that this species is parasitic on earthworms and Lebedev and Favenkov (1929) state that it is parasitic on *Dilachnus pini* L.

Sarcophaga sinuata Mg. One specimen of this species was reared from the field collections, from a puparium collected on July 25, 1947. Hayes (1938) and Buckell (1945) reported the species as a parasite of grasshoppers.

COLEOPTERA

CARABIDAE

Bembidion quadrimaculatum (L.). Larvae were taken only in the field collections from swedes. Adults from overwintered pupae emerged during the first half of June. A species of this genus, *B. lampros* (Hbst.), has been reported by Schoyen (1916) as destroying large numbers of young cabbage plants.

HYDROPHILIDAE

Cercyon sp. Larvae were taken in the field collections from swedes in the autumn of 1947. Emergence from overwintering pupae began the first of June in 1948.

STAPHYLINIDAE

Oxytelus sp. Larvae were present in the field collections from swedes in 1947.

Quedius sp. In the fall field collections from swedes a few puparia of this species were found each year. It was also collected in the debris from turnip root cellars.

CRYPTOPHAGIDAE

Cryptophagus sp. Larvae and puparia were taken in the field collections in 1947 from swedes. Puparia were found also in the debris from turnip root cellars.

MYCETOPHAGIDAE

Typhaea stercorea (L.). Larvae were present in field collections from both cabbages and cauliflowers in 1947. Cotton (1941) reported this species as a scavenger in immature grain and also as common in maize fields, particularly on the tips of ears with rotting kernels.

CHRYSOMELIDAE

Phyllotreta striolata (F.). Adults were generally present during the last of May and the first of June. In 1947 and in 1949 there was a heavy infestation on the transplants of cabbage and cauliflower in the hardening-off frames. Larvae appeared regularly in collections from cabbages and cauliflowers by mid June.

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Experimental Airplane Spraying for Spruce Budworm Control[1]

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Selection of the proper atomization and timing of the application are of paramount importance in forest spraying for control of insect pests. Use of the best atomization can materially reduce the dosage required, or the insecticide losses resulting from weather and other factors, or both. With the large acreages involved in most forest insect infestations, the saving of only a few cents per acre will amount to a sizeable figure. It is known, for example, that there is less loss of spray with coarse atomizations, whereas the finer atomizations result in wider swaths and more uniform deposits.

Experimental airplane spraying prior to 1951 had shown that maximum kill of the spruce budworm was obtained during a relatively short period of larval development. Any extension of it would be of much practical value in a large-scale operation. Cooperative investigations between what is now the Forest Insect Reseach Division of the Forest Service, U.S.D.A., the Province of Quebec Department of Lands and Forests, and the State of Maine Forest Service were made along these lines in 1951. In these tests, three atomizations were used at three dosage levels against two stages of larval development of the spruce budworm.

This design required 18 experimental plots and was accompanied by two check plots. The experiment was performed in typical spruce-fir stands in the northern Laurentide section of Quebec where spruce budworm populations were high and other facilities that were needed for an efficient experiment were available.

DESIGN AND METHOD.—Nine combinations of three dosages (¼ lb., ½ lb., and 1 lb. of DDT, each in 1 gallon of liquid per acre) and three spray atomizations arbitrarily called coarse (300 microns mass median diameter), medium (150 microns), and fine (80 microns), were applied in two series. The first series (henceforth called Series I) of nine plots was sprayed during the week following the opening of balsam fir buds when most budworm larvae were in the third instar. A second series (henceforth called Series II) was sprayed approximately 1 week later when most larvae were in the fourth and fifth instars.

Two airplanes and two pilots were used in this experiment. One airplane was fitted to deliver the fine spray, the other either the medium or coarse. The spray schedule was arranged so that each pilot applied each dosage-atomization combination once.

Each of the 18 plots was 10 chains square (10 acres), and in each plot 5 representative trees were chosen along each of 2 sampling lines perpendicular to the proposed flight line. This was either across the slope or down slope on the sloping plots. On the level plots, flight direction was arbitrary. One sampling line was located in each half of the plot, with its distance from the side boundary selected by a random number of 1 to 5 chains. The sample trees were selected at intervals of 1½ chains along the lines with the end ones 2 chains from the plot boundary. Suitable sample trees, if not present at the desired spot, were always found a short distance to the right or left, parallel

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to the flight line. The sample trees were balsam fir, mostly of medium size with full symmetrical crowns. Heights ranged from 25 to 80 feet with the majority 40 to 50 feet. Diameters at breast height varied from 4.4 to 11.5 inches. Eight sample trees were similarly chosen in each of two other plots to serve as checks.

The "larval drop" method of sampling was used in both check and sprayed plots. With this method, the number of larvae dropping onto a cloth tray, whose area was a known proportion of the crown projection area, and the number of dead and surviving larvae and pupae on the tree, made possible the determination of the per cent reduction for each tree. The final count of dead and surviving budworms was made 12 to 17 days after spraying. The average percentage reductions for the plots, calculated by Abbott's formula, averaged for the plot, are listed in table 1.

The insecticide deposit was sampled at mid-crown on four sides of the tree. Two of these were on opposite sides of the tree, but in a line parallel to the line of flight. The other two were also opposite each other, but in a line at right angles to the first. The samples were collected on flat aluminum plates of 1 square foot each on plots treated at 1 pound per acre. On plots treated with less dosages the plates were 2 square feet in area. The plates were held secure by four poles erected in the positions mentioned. Adjacent trees which might interfere with the deposition were trimmed or removed. The DDT deposit on the plates was determined by chemical or colorimetric methods. The average deposit per tree is shown in table 1.

The atomization of the spray deposit was checked roughly on the four sides of each sample tree by determining the size of the largest drop caught in a pad of spun glass attached adjacent to each deposit collection plate. For purposes of the experiment, it was assumed that this largest drop collected (d_{max}) was a sufficiently accurate reflection of the spray atomization at that point. Average d_{max} for all treated plots but one (on which samples were destroyed by rain) is shown in table 1.

The formulations used were oil solutions of DDT ($\frac{1}{4}$, $\frac{1}{2}$, and 1 lb. per gallon) applied at 1 gallon per acre. In each, 0.392 ounces of Dupont Oil Red dye was added per gallon

Table 1.—Spruce budworm mortality resulting from aerial sprays of various applications, deposits, and atomization.

	Treatment		Average D_{max} (Microns)	Average Deposit (DDT Lbs./A.)	Budworm Reduction (Per Cent)
	DDT (Lbs./Gal.)	Atomization			
Series 1	1	Coarse	422	0.302	86.2
	1	Medium	180[a]	.211	65.4
	1	Fine	266	.156	84.5
	0.5	Coarse	400	.162	83.2
	0.5	Medium	285	.042	58.2
	0.5	Fine	—	.016	27.9
	0.25	Coarse	482	.097	57.7
	0.25	Medium	286	.050	65.9
	0.25	Fine	94	.006	62.6
Series 2	1	Coarse	478	0.232	61.9
	1	Medium	368	.424	95.5
	1	Fine	165	.126	85.7
	0.5	Coarse	427	.090	86.1
	0.5	Medium	271	.089	95.6
	0.5	Fine	123	.066	62.8
	0.25	Coarse	538	.052	79.1
	0.25	Medium	276	.061	77.9
	0.25	Fine	82	.038	77.9
Check	—	—	—	—	4.6

[a] Based on only 13 readings and, therefore, of doubtful accuracy.

Table 2.—Average values of d_{max}, DDT deposit, per cent spray recovery, and spruce budworm reduction resulting from spraying 1, $\frac{1}{2}$, and $\frac{1}{4}$ lb. DDT per gallon per acre.

DDT Dosage (Lbs./Gal.)	d_{max} (Microns)	DDT Deposit (Lbs. per Acre)	Spray Recovery (Per Cent)	Budworm Reduction (Per Cent)
1	323	0.242	24	78.8
0.5	307	.079	16	68.4
0.25	302	.051	20	67.1

to make the droplets more visible for the d_{max} measurements. Stearman biplanes with booms and nozzles under the wings were used to deliver the sprays.

A continuous record of wind velocity and direction was taken during all spray operations. This was done by use of a recording, sensitive type anemometer and a recording windvane. Both were mounted above the forest canopy as near as practical to the center of each series of plots. The maximum wind recorded during any of the spray operations was 2.4 mph.

To help the pilot locate and maintain orientation with respect to the plot, its four corners were marked either by permanent stuffed feed sacks raised above the canopy or temporarily during spraying of that plot, by captive balloons. In all cases spraying was conducted shortly after sunrise when the air was relatively calm, varying from zero to 2.4 mph. Nine parallel swaths, 2 chains apart, were flown over each plot, thus covering not only the plot but also a buffer zone around each plot 4 chains wide. In crosswind conditions the swaths were offset several chains upwind. The flying altitude was held as close to 50 feet above the canopy as obstacles and terrain permitted, and the plane speed was held as close as practical to 80 miles per hour.

RESULTS.—The data on droplet size, DDT deposit, and budworm mortality were first analyzed separately by analysis of variance.

The differences between the mean d_{max} for three atomizations were highly significant, whereas d_{max} differences between dosages were not significant. The mean values obtained are given in tables 2 and 3.

Deposit of DDT by the finely atomized spray was significantly less than that by the coarse and medium sprays (see Table 3). No real difference was shown between the latter two. The per cent recoveries for the coarse, medium and fine sprays were, respectively, 28, 22, and 10. However, the per cent recovery of the fine spray may be higher on a large acreage because there the drift will not be so completely lost as on the small test plots.

There was no significant difference in deposit of DDT between Series I and Series II, averaging 0.116 and 0.132 lb. per acre, respectively. A significant difference was found between the deposits which were applied by the two pilots, the averages being 0.099 and 0.149 lb. per acre.

Application of DDT at the rate of 1 lb. per acre resulted in significantly greater deposit on the plates than that from the $\frac{1}{2}$ and $\frac{1}{4}$ lb. dosages (see Table 2). The difference in mean deposit between the $\frac{1}{2}$ lb. and the $\frac{1}{4}$ lb. dosages. though noticeable, was not statistically significant. These mean deposits represent recoveries of 24, 16, and 20 per cent of the volume applied, respectively, which is as much as one would expect in view of the screening effect of the forest canopy.

The mean deposits for the nine treatments generally re-

Table 3.—Average values of d_{max}, DDT deposit, per cent spray recovery, per cent budworm reduction, LD 95 and its standard error with respect to coarse, medium, and fine atomizations.

Atomization	d_{max} (Microns)	DDT Deposit (Lbs. per Acre)	Spray Recovey (Per Cent)	Budworm Reduction (Per Cent)	LD 95 (Lbs. DDT/Acre)	Standard Error of LD95 (Lbs. DDT/Acre)
Coarse	457	0.158	28	75.2	0.220	±0.19
Medium	291	.146	22	72.4	.111	±0.10
Fine	151	.068	10	66.7	.260	±0.31

flected well defined differences for the three atomizations and three dosages. The 1 lb. in 1 gallon per acre dosage with medium and coarse atomization gave significantly higher deposit than all other treatments, while lightest deposits were obtained by the $\frac{1}{2}$ and $\frac{1}{4}$ lb. per gallon per acre fine spray treatments.

No correlation was shown between estimated initial budworm population on a tree and the resultant mortality per cent. The difference between pilots on the control obtained was significant,—64.8 as compared with 81.2 per cent.

The per cent reduction effected on all sample trees in the early series was significantly less than on those in the late series, the means being 64.0 in the first and 78.9 in the second.

The differences in mean per cent reduction effected by the three dosages, the three atomizations, and the nine combinations of both were not statistically significant. This was largely a result of their being applied at different times. The mean budworm reduction obtained by each dosage is given in table 2 and for each atomization in table 3.

For very high per cent control of the spruce budworm, the minimum required dosage appears to be 1.0 lb. per acre. The deposit of insecticide in airplane spraying, being dependent on a number of factors, is highly variable from tree-to-tree; for example, mortality values for individual trees in plot 18, where a medium atomization was used at 1 lb. per gallon per acre were as follows: 99.7, 99.7, 98.2, 60.1, 99.8, 99.4, 98.6, 99.6, 99.6, and 98.0; averaging 95.3 per cent.

The tree with 60.1 per cent mortality showed a deposit of only 0.034 lb. per acre while the other deposits ranged from 0.169 to 0.837 lb. per acre.

To provide a more discernible and reliable measure of the efficiency of the various treatments, a multiple linear regression analysis was made, with the DDT deposit and budworm mortality values transformed to logarithms and probits, respectively. The d_{max} values were not included as no droplet size record was obtained for a number of trees. This regression analysis largely corroborated the relationships indicated by the earlier separate analyses. First, the relationship between deposit and mortality proved to be highly significant. The control obtained by the second series of sprays was definitely higher than the control effected by the first series. Deposit-mortality calculations based on the second series alone showed that the medium spray on the average was most efficient and consistent. Its LD 95 was 0.111 lb. DDT per acre as compared with 0.220 for the coarse and 0.260 for the fine sprays, respectively. The medium spray also had the narrowest confidence band (Figure 1). The LD 95's for the three atomizations are shown graphically in figure 2.

Summary.—Aerial sprays of three different atomizations, fine, medium, and coarse, were applied at three dosages, $\frac{1}{4}$, $\frac{1}{2}$, and 1 lb. per acre, at two stages of larval development ((1) when most of the larvae were in the third instar and (2) when most of them were in the fourth and fifth instars) to determine the combination effecting greatest reduction of the spruce budworm. The design consisted of 18 experimental plots and 2 check plots with

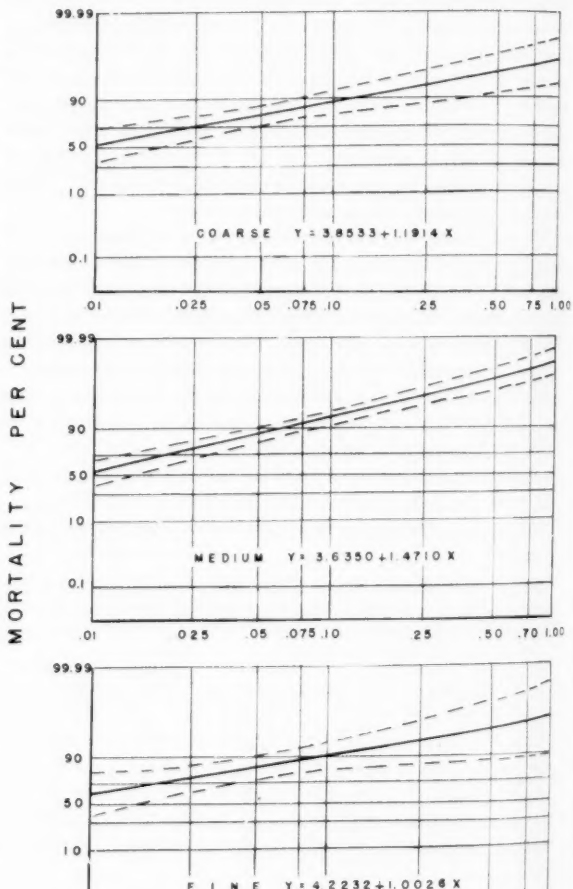

Fig. 1.—Deposit-mortality relationships of coarse, medium and fine sprays.

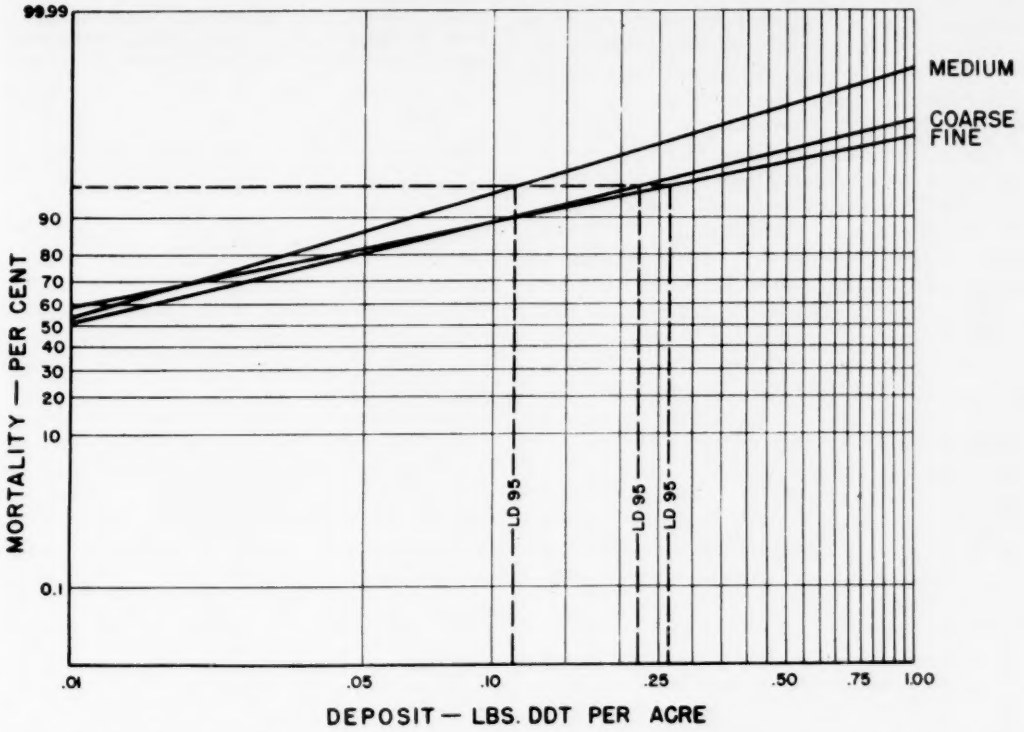

FIG. 2.—Deposit-mortality lines for coarse, medium and fine sprays with the respective LD 95's.

10 sample trees per plot. At each tree DDT deposit and budworm mortality were measured. From this the following conclusions were drawn:

The optimum time to begin spraying for maximum kill of spruce budworm is when most of the larvae are in the fourth and fifth instars.

One pound of DDT per acre is the minimum dosage for control operations where maximum kill is desired.

A spray of medium atomization (150 microns mass median diameter) proved more consistently effective than sprays of coarser or finer atomization (300 or 80 microns mass median diameter). The average deposit from the medium spray required to effect 95 per cent mortality of budworm larvae mostly in the fourth and fifth instars was determined to be 0.11 lb. DDT per acre. For the coarse and fine sprays it was 0.22 and 0.26 lb. per acre, respectively.

Fly Control in Wyoming Barns[1]

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In many parts of the United States, house flies (*Musca domestica* L.) are no longer effectively controlled with the chlorinated hydrocarbon insecticides. Where flies are resistant to these insecticides, organic phosphorus compounds such as malathion, Diazinon, Pirazinon, Bayer L 13/59 and others have been used more or less successfully as sprays or baits. Diazinon was first used by Hansens & Bartley (1953) in New Jersey and gave from 3 to 10 weeks' control of non-resistant house flies and 4 weeks' control of resistant flies. Later, Hansens & Scott (1955) obtained 40 to 50 days' control of house flies with Diazinon and nearly as good control with Pirazinon under weather conditions unfavorable for fly breeding. Wingo (1954) reported 35 days' control with Diazinon in Missouri under conditions of heavy populations and poor sanitation, while Hoffman & Cohen (1954) using several organic phosphorous insecticides, including Diazinon, did not obtain more than 2 weeks' control in barns in California. Bruce (1953) obtained 16 to 25 weeks' control with a varnish bait (1½ g. Bayer L 13/59 per pint of dark Karo syrup) in Grade A dairy barns and high reductions of flies for 2 to 26 weeks in various other buildings.

Decidedly resistant fly populations may occur locally in Wyoming, but do not appear to be widespread. Tests in 1953 at lower elevations in southeastern Wyoming, where resistance might be expected to show up first, indicated that resistant fly populations were not as yet a major factor in control operations in Wyoming. This is probably the case in much of the mountainous West,

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where house flies have a comparatively short season of only two to three generations per year. In the 1953 tests, residual sprays of 2% methoxychlor made from wettable powder gave up to 6 weeks' control to the end of the season in dairy barns at Torrington, Wyoming (elev. 4100 ft.), near the Nebraska state line, and 8 weeks' control to the end of the season at Laramie (elev. 7200 ft.). Methoxychlor or lindane had been used in most of these barns for a number of years. Methoxychlor, 0.5%, gave only 2 weeks or less of satisfactory control but killed a great many flies for a longer period. Results in 1955 with methoxychlor in dairy barns were not as good as in 1953, but still were satisfactory. Longer control with methoxychlor was observed in some other barns during 1954 and 1955 than was secured in these tests. It is not unusual, up to the present time, to enter a barn in early summer and see an appreciable number of flies, including *M. domestica*, dying from spray deposits applied in previous years. List (1952) reported a similar observation in Colorado.

In a laboratory study of Laramie house flies, Ritchie (1954) found only a moderate resistance to DDT and chlordane, not enough to be discernible in field-control operations. The City had used DDT, chlordane, and BHC for several years in an alley-spraying program. In the laboratory studies by Ritchie, 92.7% of Laramie flies survived a 10-minute exposure to 10 mgs. DDT per sq. ft. while none of a non-resistant strain obtained from Julius Hyman Co. survived. At 200 mg. DDT per sq. ft., 2.5% of the Laramie flies survived. Exposure to 10 mg. DDT per sq. ft. for 5 minutes resulted in 100% mortality of Hyman flies, while 320 minutes' exposure was required for 100% mortality of Laramie flies. The time required for 50% knockdown of flies exposed to 50 mg. DDT per sq. foot was 10 and 12 minutes, respectively, for Laramie and Hyman flies, and 33 and 17 minutes, respectively, to obtain 100% knockdown. With chlordane at 10 mg. per sq. ft. it took twice as long (75 min.) to obtain 50% knockdown of Laramie flies as it did with Hyman flies, and six times as long to obtain 100% knockdown (287 min.)

Although control with methoxychlor was still considered satisfactory in dairy barns, it was deemed desirable to determine whether the organic phosphorus compounds might give better control under the above conditions which pertain in Wyoming. In a single test in 1954, Diazinon had given remarkable control in a farm milking barn. In addition, varnish baits were tested as a possible control measure in open, unsanitary livestock shelters where residual sprays of chlorinated insecticides do not give satisfactory control.

DAIRY BARN FLY POPULATIONS.[2]—Flies do not ordinarily become a problem necessitating control in Wyoming dairy barns until late June or early July. House flies normally do not appear before the first of July and do not form the dominant part of the barn fly population until late July or early August. The anthomyid, *Muscina stabulans* (Fall.), and calliphorids, mainly *Phaenicia sericata* (Mg.), form the bulk of the fly population during June and July. During those months *M. stabulans* is found in all barns and frequently in large numbers. *P. sericata* may occur in tremendous numbers in some barns. The lesser house fly, *Fannia canicularis* (L.), does not appear to be of particular importance, but does occur in small numbers. Many *Stomoxys calcitrans* (L.), are sometimes found inside the barns, after being carried in on the cows, but the grill placings were not conducive to high counts. The make-up of the fly population in seven dairy barns in 1955, as determined during Scudder grill counts, is shown in table 1.

Table 1.—Seasonal incidence of major species of flies in seven Wyoming Grade A. Dairy Barns during 1955.

Month	Per Cent of Total Population			
	Musca domestica	*Muscina stabulans*	*Calliphoridae*	*Stomoxys calcitrans*
June	0	81	19	0
July	22.8	40.5	33	2.5
August	78.4	14.6	3	3.8
September	95	0.7	0	0.7

Small gnats frequently are a source of some annoyance to Wyoming dairymen because of the large numbers entering the barns. A small sample of these collected from windows and sent for identification to the Insect Identification and Parasite Introduction Section, U. S. Dept. of Agriculture, included 16 *Hippelates bishoppi* Sabr. (Chloropidae), 17 *Scatopse fuscipes* Mg. (Scatopsidae), and 10 *Leptocera vagans* (Hal.) (Sphaeroceridae). They congregate on windows and are readily killed by residual sprays.

MATERIALS AND METHODS.—In 1955, a number of dairies were treated with organic phosphorous insecticides to determine whether they would give better control than methoxychlor. Malathion, Diazinon, or methoxychlor were used as residual sprays applied at 200 p.s.i. to the point of run-off to walls, ceilings, and stanchions. Diazinon and methoxychlor were used as wettable powders only at concentrations of 1.0% and 2.0%, respectively. Malathion sprays, both from wettable powder and emulsifiable concentrate, were used at a concentration of 1.25%. In one barn sprayed with malathion, sugar was added at rate of 2½ lbs./12½ gal. of water. About 5 to 7 gallons of spray material were applied in the average barn of approximately 300 to 500 square feet of floor space. In barns in which Bayer L 13/59 varnish baits were tested, they were applied with a small paint brush near areas where flies tended to congregate (Bruce 1953). From 1 to 5 grams of technical Bayer L 13/59 were dissolved in 4 oz. of water and then mixed with 1 pint of dark Karo syrup.

In barns, the data from which are shown in table 2, fly abundance was measured by placing a yard-square Scudder fly grill at four points in the barn where flies were the most numerous. A barn was considered to have too many flies when a total of 12 or more were counted on the four grill settings. If a count of 12 or more was secured in 2 successive weeks, control was considered to have ended with the first high count. However, if the first high count was not substantiated by a high count the following week, control was considered to extend to the date of the second high count of 12 or more. When a count in the neighborhood of 25 or more flies was secured, no substantiating high count the following week was necessary, and the barn was usually re-treated immediately. Because of distance that had to be traveled, barns were checked only once a week.

For barns, the data from which are shown in table 3, the grill counts were made daily and pretreatment counts

[2] Muscoid flies were determined by Dr. M. T. James, Scatopsidae by Alan Stone, Sphaeroceridae and Chloropidae by C. W. Sabrosky.

Table 2.—Comparison of insecticides against flies in Wyoming barns in 1955.

Dairy Barn or Premises	Treatments[a]	Date Treated 1955	Scudder Grill Counts After Weeks Indicated										
			Pre-treatment	1	2	3	4	5	6	7	8	9	10	11
Damrow	1.0% Diazinon	8/17	13	7	2	3	13	3						
Hughes	1.0% Diazinon	7/7	212	1	2	2	4	15	8	5	3	7	0	3
Walter	1.0% Diazinon	7/12	13	0	7[b]	0	0	4	0	—	0	0	0	
Damrow	2.0% methoxychlor	7/7	14	4	3	23[c]								
Rife	2.0% methoxychlor	8/17	17	2	2	25[c]								
Shayne	2.0% methoxychlor	7/7	23	6	9	12[c]	24							
University	2.0% methoxychlor	7/19	14	0	1	—	33[d]	6	6	6	4	2		
Rife	1.25% malathion	7/7	149	15[c]	12									
Shayne	1.25% malathion plus sugar	8/23	28	1	13[c]	21								
Damrow	Bayer L 13/59 bait	8/4	19	70[c]										
Hauf	Bayer L 13/59 bait	7/7	111	6	3	4	6	2	12	9	24[c]			
Shayne	Bayer L 13/59 bait	8/4	24	9[b]	9	28[c]								
Hauf	Bayer L 13/59 bait	8/30	24	1	7	19[c]								
Britthouer milking barn	1.0% Diazinon	7/12	21	1	10	0	3	5	6	22[c]				
Hughes calf shed	1.0% Diazinon	7/7	17	6	11	13	6	18[c]						
Irvine ranch	1.0% Diazinon	8/5	46	—	0	3	0	0	0					
Hughes calf shed	Bayer L 13/59 bait	8/30	15	23[c]										

[a] Materials used were wettable powders except malathion on August 23 was emulsion concentrate; and Bayer L 13/59 bait formulation contained 2½ grams technical material per pint of Karo syrup on July 7 and August 4 and 1 gram per pint of Karo syrup on August 30.

[b] Count includes several *S. calcitrans*.

[c] indicates end of control.

[d] Nearly all of these flies, *Musca domestica*, were "wobbly." There had been an influx into the barn through an open door next to two silos, the leakage from which attracted hordes of flies. This situation persisted for several weeks while the silos were being filled, but control was maintained in the barn.

were made on each of 2 or 3 days immediately preceding application of bait. There was usually a rather definite reduction in percentage of control after the indicated number of days. Where percentage reduction is given for specific days such as first and eighth, etc., counts were not made on intervening days.

Discussion.—Results of the various treatments in 1955, both in Grade A dairies and other livestock structures, are shown in table 2. Diazinon wettable powder at 1.0% concentration was considerably better than any of the other insecticides used. It gave from 4 to 10 weeks of excellent control in dairies, and in all cases one treatment gave satisfactory control to the end of the season, ranging from 5 to 11 weeks' duration. It also performed well in structures other than dairy barns. The control obtained in the Britthouer milking barn and the Hughes calf shed was excellent considering the sanitation conditions prevailing. Control was also excellent at the Irvine Ranch near Wheatland, although spraying was confined to a barn housing horses part time, and in which the milking was done, and a small building near the house where the milk separator was kept. Dry weather toward the end of the season may have had a beneficial influence on the effect of this treatment.

Methoxychlor wettable powder at 2.0% concentration gave 3 weeks' control in each of three dairies at Torrington and 9 weeks' control to the end of the season in one barn at Laramie. Control was not quite as good as that experienced with methoxychlor in 1953, but was definitely better than with malathion, which gave only 1 to 2 weeks' control in the two barns in which it was used.

Bayer L 13/59 varnish bait generally gave good to fair control in dairies for about 3 weeks from a single application of bait both in 1954 and 1955 (Tables 2 and 3). In the one barn (Damrow) in which the bait was completely ineffective, it was nearly all removed by the dairyman in the process of the daily clean-ups after milking. The large

Table 3.—Fly control in 1954 with varnish bait containing 5 grams of technical Bayer 13/59 per pint of Karo corn syrup.[a]

Type of Building	Pre-treatment Fly Count	Reduction After Treatment	
		Per Cent	Days
Univ. Veterinary Shed	164	88	12
Bower Shed	64	87	5
Hughes Calf Shed	56	85	1
		51	8
Hughes Calf Shed	112	89	1
		76	7
Klouda Calf Barn	172	83	3
		61	4–10
Feighny Milking Barn	28	63	8
Univ. Dairy Calf Barn	280	74	7
Klouda Calf Barn	256	93	3
		66	4–10
Klouda Calf Barn	68	84	2
		59	4
Univ. Dairy Calf Barn	160	75	4
Univ. Beef Barn	88	78	13
Univ. Beef Barn	156	74	5
Hughes Dairy Barn	44	93	15
Hughes Dairy Barn	20	86	7
		67	14
Hauf Dairy Barn	92	93	14

[a] Fly abundance measured by four yard-square Scudder fly grills placed where flies were most numerous.

amount of water used in this barn and splashed well up on the walls during cleaning also probably reduced the effectiveness of Diazinon and methoxychlor deposits in other tests.

Contrary to observations elsewhere on some types of baits, it was noted that blowflies and house flies accustomed to feeding on molasses-sweetened feed were rapidly attracted to the bait. Such feed might be "black" with flies, but would be nearly cleared of them within a few minutes after bait was applied nearby.

Table 3 shows results of applying Bayer L 13/59 varnish bait in various types of livestock shelters in 1954, where very poor sanitation conditions prevailed. In such buildings, where frequently there is heavy breeding or where numerous openings are present through which flies enter and congregate, a count of 50 to more than 100 flies may be obtained in a single placing of a Scudder fly grill. Chlorinated insecticide sprays knock these populations down for a few days but such frequent respraying is necessary that it is not practical. The bait usually reduced such populations by about 75 to 90% for a period ranging from a few days to nearly 2 weeks. This reduction could not be termed excellent control but populations were reduced tremendously without aid of good sanitation. In such situations varnish baits might have limited usage, particularly in supplementing residual sprays.

A disadvantage of varnish bait in some calf barns was the fact that calves were very prone to lick off fresh bait when it was applied low enough on walls to attract flies from floor litter. Also, some of the best potential spots for bait application could not be used since it resulted in piles of dead flies accumulating in feed troughs or water containers. Another obvious disadvantage of baits in such situations is that no control of stable flies is obtained. In the dry climate of Wyoming, no trouble was experienced with the bait remaining sticky.

SUMMARY.—In southeastern Wyoming, residual sprays of Diazinon at 1.0%, methoxychlor at 2.0%, and malathion at 1.25%, with or without sugar added, were effective in that order in controlling flies in dairy barns in 1955. In dairy barns Diazinon gave control to the end of the season, a period ranging from 5 to 11 weeks. In comparable tests, methoxychlor gave 3 weeks' control, and in one barn at 7200 ft. elevation gave 9 weeks' control to the end of the season. Malathion gave control for 1 week in one barn and 2 weeks in another when 2½ pounds of sugar per 12½ gallon of water was added. Bayer L 13/59 varnish bait gave about 3 weeks' control in dairies and is considered a satisfactory control measure although not as effective as residual sprays of Diazinon or methoxychlor.

In limited tests, Diazinon gave good control in structures such as milking barns and calf barns. In such buildings, Bayer L 13/59 varnish baits were not entirely satisfactory used alone although they gave a high initial reduction of flies.

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Broadcast Treatments with Insecticides and Soil Fumigation for Tobacco Wireworm Control[1]

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The principal means used in attempting to control tobacco wireworms on tobacco has been the use of insecticides added to the transplanting water. A 4-year study of insecticides, formulations, and concentrations using hand setters has been reported by Allen *et al.* (1954). Tests conducted recently indicate that treatment of the transplanting water gives good results when hand setters are used but will not give satisfactory control of wireworms with the majority of mechanical setters (Rabb *et al.* 1955). Since most tobacco is set with mechnical setters it appears that means of control other than treated transplanting water need investigation.

The use of fumigants to control nematodes on tobacco has been under investigation for a number of years and considerable interest has been shown in the effect of fumigation on wireworm control. Many farmers believe that fumigation for nematode control also gives satisfactory control of wireworms.

This paper reports the first year's results of tests conducted to evaluate control of wireworms attacking tobacco by use of broadcast treatments of insecticides. In addition, the effect of row and broadcast applications of EDB and DD on tobacco wireworms and the results of a 2-year survey of farmer use of fumigants are reported.

REVIEW OF LITERATURE.—Broadcast applications of organic insecticides for control of wireworms were first reported concurrently by Greenwood (1947), and Pepper

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et al. (1947) on potatoes. Similar tests have been conducted by numerous other workers on a variety of crops. Greenwood (1948) presented a preliminary report on the use of BHC and chlordane as broadcast treatments against wireworms attacking tobacco. Allen *et al.* (1954) reported tests on tobacco where insecticides added to the furrow shortly before transplanting gave wireworm control inferior to that attained with use of treated transplanting water.

Considerable emphasis to the control of nematodes on tobacco was given when Kincaid & Volk (1948) reported effective control with DD and EDB. These results were confirmed by various state and federal agencies, and it is estimated that about 25% of all tobacco acreage is now treated with soil fumigants for control of nematodes. Although fumigation for wireworm control had been investigated for many years, no material had been found until recently which was feasible for farmer usage. Stone (1944) reported that soil fumigation with DD in emulsion form as sprays was very effective for control of wireworms. Lange (1948) reported tests with DD and EDB applied in the soil by drills spaced 12 to 15 inches in which satisfactory control of wireworms was obtained. These tests were conducted under different soil and climatic conditions and on different species of wireworms than those found in the tobacco belt. Allen *et al.* (1954) observed that fumigation for control of nematodes on tobacco had little effect on wireworms, but no extensive tests or surveys of the effectiveness of fumigation on tobacco wireworms have been reported.

MATERIALS AND METHODS.—*Broadcast applications of insecticides.*—All materials were applied with an Easy-Flow fertilizer spreader in mid-March of 1955 at the rates indicated in table 1. Formulations used were as follows: 2% dieldrin, 2% aldrin, and 5% chlordane granulated materials, and 2½% heptachlor and 2% endrin dusts. The materials were applied to soil which had been broken and harrowed and were disked into the soil within 72 hours. In one test, table 1 (Test 1), the soil type was a loamy sand, and in the second test, table 1 (Test 2), the soil type was a sandy clay loam. In test 1, the plots were 0.138 acres in size and were replicated three times. The plots in test 2 were 0.142 acres in size and were replicated four times. These fields were set in mid-April with untreated setting water using mechanical setters. Two weeks after setting, 40 plants in the center of each plot of test 1 and 50 plants in each plot of test 2 were pulled and scored for wireworm injury and general plant condition. The stem of each plant was washed and carefully examined to determine the severity of wireworm injury. None of the treatments indicated any effect on plant growth which could be attributed to insecticide injury during any part of the growing season. All wireworms found in the test areas were *Conoderus vespertinus* (F.). The effectiveness of the various treatments on wireworm injury is shown in table 1.

Fumigation tests.—The effect of soil fumigation on wireworm control was evaluated under two conditions: experimental plots, and a farm survey of fumigant-treated fields. The experimental plots used for nematode control studies by the North Carolina State College Plant Pathology Department at a number of locations throughout the state were evaluated for wireworm control 2 weeks after setting in 1953, 1954, and 1955. Unless otherwise indicated, the broadcast treatments were applied in 12-inch bands to a depth of 6 inches, and the row applications were applied to the same depth in the middle of each furrow. The 1953 experiments were conducted at Whiteville, North Carolina, and consisted of 15 treatments replicated twice. Each plot was 69 plants long and 4 rows wide. Fall applications were made in November and spring applications in March. In 1954 the experiments were located

Table 1.—The effectiveness of broadcast applications of insecticides to control wireworms attacking tobacco.[a]

Material	Pounds Actual per Acre	Per Cent of Plants[b] Showing Slight Damage	Bored or Bored and Tunnelled[c]
	TEST NO. 1		
Chlordane	6.3	12	7.33
Aldrin	4.2	16	7.33
Dieldrin	2.1	11	6.07
Check	—	28	27.17
L.S.D. at 5% level			(7.8)
	TEST NO. 2		
Endrin	1.7	8	19.60
Dieldrin	2	7	2.03
Heptachlor	3.6	8	2.03
Aldrin	4	6	4.05
Check	—	9	44.75
L.S.D. at 1% level			8.7

[a] Plots treated on March 14, 1955 and examined for injury on April 9, 1955.
[b] Number of plants examined per treatment in test no. 1 was 120 and in test no. 2, 200.
[c] Transformed to angles for statistical treatment.

Table 2.—The effect of soil fumigation on the control of tobacco wireworms in experiments conducted for control of nematodes.[a]

Treatment	Gallons per Acre	Method of Application	No. Plants Examined	Per Cent of Plants Bored or Bored and Tunnelled
1953 Experiments—(2 replications per treatment)				
DD[b,c]	20	Broadcast	100	18
W-40[b,d]	16	Broadcast	90	11
DD	15	Broadcast	100	28
DD	20	Broadcast	200	18
W-40	15	Broadcast	100	15
W-85[e]	4.5	Broadcast	100	16
			Average	18
DD	7.5	Row	100	36
DD	10	Row	200	33
W-40	7.5	Row	100	24
W-40	5.66	Row	100	30
W-40	7.5	Row	100	42
			Average	34
None	—	—	200	41
1955 Experiments—(3 replications per treatment)				
W-85	2	Row	90	36
DD	10	Row	90	29
None	—	Row	90	38

[a] Tests against nematodes conducted by C. J. Nusbaum, Department of Plant Pathology, North Carolina State College.
[b] Indicates fall treatment; others made in spring.
[c] Dichloropropane-dichloropropene mixture.
[d] 40% (by weight) of ethylene dibromide.
[e] 85% (by weight) of ethylene dibromide.

Table 3.—The effect of soil fumigation on the control of tobacco wireworms in experiments conducted for the control of nematodes.[a]

Treatment	Gallons per Acre	Per Cent of Plants Bored or Bored and Tunnelled by Wireworms: County and Number of Plants Examined — Forsyth 20	Guilford 25	Edgecomb 50	Robeson 50	Wayne (1) 50	Wayne (2) 25	Average All Tests
DD	10	0	16	10	14	10	72	20
W-85	2	0	20	2	12	14	96	24
PN-20[b]	7.5	0	32	12	12	18	100	29
Check	—	20	40	10	26	24	88	35

[a] Tests conducted by the Department of Plant Pathology, North Carolina State College in 1954 on unreplicated plots at six locations in North Carolina. All treatments were applied in the spring by row equipment.
[b] 20% (by weight) of ethylene dibromide in a solvent manufactured by Philips Oil Company.

at six locations throughout the state. Three treatments and an untreated check were made on 1/13th acre unreplicated plots at each location. In 1955 the experiments were located at Rocky Mount, North Carolina, and the treatments were applied to triplicated plots, 6 rows wide and 22 plants long. Each of these experiments was scored for wireworm injury as described above, and the fumigants, rates, method of application, and results are shown in tables 2 and 3.

In order to supplement data from the experimental plots, a survey was made of a number of farms in North Carolina in 1954 and 1955. The fumigant, type of application, and rate of application were recorded, and a number of plants from each field was scored as explained previously. If an untreated area was left in the same field, it was also scored for damage. The majority of wireworms encountered in all the fumigation tests were *Conoderus vespertinus*. The results of the survey are shown in table 4.

RESULTS AND DISCUSSION.—*Broadcast treatments of insecticides.*—The data shown in table 1 indicate that excellent control of wireworms attacking tobacco may be attained with broadcast applications of heptachlor, dieldrin, and aldrin under heavy wireworm infestations. Chlordane was not tested under conditions of heavy wireworm attack but gave good results under moderate wireworm infestations. Appreciable control was attained with endrin, but it was not as effective as the other materials. Further studies are now in progress to determine the longevity of control of a single treatment, the effectiveness of applications of insecticides in the row during fertilization or similar farm practices, and the use of different formulations.

Fumigation tests.—In both experimental plots (Tables 2 and 3) and a survey of several farms (Table 4), row fumigation of tobacco generally gave some decrease in wireworm injury, but control was not considered practical. Wireworms caused appreciable commercial damage in many heavily infested fields which had been fumigated.

Data are considered too few for conclusive evaluation of broadcast application of fumigants to control wireworms. The data collected indicate that broadcast applications were more effective than row applications of fumigants for the control of wireworms. The trend for fumigation of tobacco land for nematode control is toward the row application method.

Although tests were not critical enough to be considered conclusive, there did not seem to be an appreciable difference between EDB and DD for control of wireworms at rates recommended for use against nematodes, and no difference could be found between spring or fall applications of fumigants.

Table 4.—The results of a survey to determine the effectiveness of soil fumigation against tobacco wireworms in North Carolina in 1954 and 1955.[a]

County	Treatment	Gallons per Acre	Method of Application	No. Plants Examined	Per Cent of Plants: Bored or Bored and Tunnelled	Injured In Check[d]
Robeson	DD	15–20	Broadcast[b]	48	69	
Robeson	DD	15–20	Broadcast[b]	48	29	
Pitt	DD	20	Broadcast[c]	25	4	25
Pitt	W-85	4.5	Broadcast[c]	25	20	92
Pitt	W-85	4.5	Broadcast[c]	25	40	
Onslow	W-85	4	Broadcast[c]	25	20	44
Wilson	DD	10	Row	75	95	
Wilson	DD	10	Row	120	21	
Wilson	DD	10	Row	200	50	66

[a] All treatments were applied by farmers in the spring.
[b] 16-inch bands.
[c] 10-inch bands.
[d] When otherwise comparable untreated areas were available.

SUMMARY.—Broadcast applications of dieldrin, endrin, heptachlor, aldrin, and chlordane were made to 1/10-acre plots in two locations. Dieldrin, heptachlor, and aldrin gave excellent control of heavy infestations of tobacco wireworms. Chlordane was not tested against a heavy infestation but showed good results against a moderate infestation. Endrin gave significantly better control than the check but was inferior to the other treatments. These preliminary tests indicate that broadcast treatments may provide a satisfactory means of wireworm control, particularly in those situations where unsatisfactory results have been obtained with insecticidally-treated transplanting water.

Soil fumigation as practiced for nematode control in tobacco did not give satisfactory control of tobacco wireworms when applied as a row application. The broadcast type of soil fumigation gave better control than the row method, but control would not be considered adequate under conditions of heavy wireworm infestation. Little difference was noted between DD or EDB as used for the control of wireworms.

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Control of the Northern Fowl Mite and Two Species of Lice on Poultry[1]

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Control of mites and lice of poultry is often neglected because of the lack of an easy, rapid method of treatment and safe, effective toxicants. Control of these parasites in large flocks by dropper or pinch treating (Bishopp & Wood 1939) of individual birds is obviously impractical. Dipping birds is also too time-consuming and endangers the health of the birds in cool weather, especially in the more northern States. Roost paints containing nicotine sulfate usually cause a high initial mortality of mites and lice, but continued control is erratic, according to Payne (1929), Ritcher & Insko (1948), and Furman (1953). This method is not very effective where birds are reared on wire.

Recent studies with the chlorinated hydrocarbon and phosphorus insecticides for the control of external poultry parasites have been conducted largely on a laboratory scale. However, Furman (1952) reported good control of the northern fowl mite with 10% Neotran dust and 0.5 to 2% Neotran sprays applied as flock treatments. Furman likewise reported that 5% methoxychlor, 5% DDT, and 0.5% lindane dusts were ineffective. Limited tests by Vincent *et al.* (1954) showed malathion to be promising against this mite when applied as a dust to litter. Furman *et al.* (1955) obtained effective control by spraying birds with emulsions containing "less than 0.5 per cent" of malathion.

Louse control was obtained by Fairchild & Dahm (1955) with several of the chlorinated hydrocarbon insecticides at the rate of 15 grams of dust per bird. These authors also reported good control by litter applications of 1.5% aldrin, 5% chlordane, and 1% lindane at the rate of 2 pounds of dust per 100 square feet.

This paper is concerned primarily with the evaluation of several of the new insecticides for the control of the northern fowl mite (*Bdellonyssus sylviarum* (C. & F.)), the chicken body louse (*Menacanthus stramineus* (Nitz.)), and the shaft louse (*Menopon gallinae* (L.)) on white leghorn hens by simple rapid methods of flock treatment under Oregon conditions. Flocks on wire and on sawdust litter were used. Additional tests were conducted with four insecticides as litter treatments for the control of poultry lice. Dusts were used in most of the tests because of the undesirability of wetting birds during the winter months in Oregon. A few spray tests were completed in the spring after the weather moderated.

METHODS.—In screening tests against the northern fowl mite, individual hens were dusted in the laboratory. Two methods of application were used—hand dusting, in which the feathers were ruffled during application to insure penetration, and sprinkle dusting, in which the dust was sifted over the bird while it was confined in a wire-floored exhibition-type cage. Five grams per bird were used in hand dusting, and three in sprinkle dusting. Some of the birds dusted with malathion were retained in the same cages in which they were dusted, but others were placed in clean cages following treatment.

In field tests dusts were applied at night to flocks on wire, either with a rotary or pump-gun duster or by sprinkling over the backs of the birds. In litter and nest treatments dusts were applied at rates of 1 pound to each 40, 50, 100, or 200 square feet of floor area. Malathion emulsion sprays were applied to hens on wire at the average rate of 25 ml. per bird, with a 3-gallon compressed-air sprayer that produced a moderately coarse cone-shaped spray.

Mite populations were based on the average number of mites observed per feather examined and rated as follows: —light, 1 or less; moderate, 1 to 3; heavy, more than 3. Five feathers were examined at each of four locations—the vent, the neck, and both wings. Following laboratory treatment the birds were examined in the same manner to establish the degree of control. In flock treatments the degree of infestation was estimated from a general examination of 20 to 30 birds. All birds examined had mites prior to treatment.

Four per cent dusts of Chlorthion, malathion, and DDT and a 1% lindane dust were applied to sawdust litter for the control of the body louse and the shaft louse. Additional tests on individual birds were run in the laboratory to evaluate malathion against lice.

RESULTS.—*Treatment of Individual Birds.*—Results of the screening tests against the northern fowl mite are given in table 1. All the 5% dusts except DDT gave immediate control by the hand-dusting method. Lindane

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Table 1.—Effectiveness of various dusts applied to individual white leghorn hens for the control of the northern fowl mite.

Insecticide	Per Cent Concentration	Per Cent Control After—(Days)			
		1 or 3[a]	8 or 15[b]	30	45
	Hand dusting (5 grams per bird)				
Lindane	1	99	100	100	—
DDT	5	20	30	0	—
Lindane plus DDT	1 plus 5	99	100	100	—
Lauseto neu	5	99	100	100	—
Bayer 21/199	5	100	100	100	—
Am. Cyanamid 4124	5	100	100	100	—
Bayer L 13/59	5	100	100	100	—
Chlorthion	5	100	100	100	—
Malathion	5	100	100	100	—
	Sprinkle dusting (3 grams per bird)				
Bayer L 13/59	1	30	0	0	—
	2.5	100	100	100	—
Chlorthion	1	100	100	100	95
	2.5	100	100	100	100
Malathion: Birds held in same cage	0.25	0	0	0	—
	.5	25	90	100	100
	1	90	100	100	—
	1	100	100	100	—
	2.5	100	100	100	—
	5	100	100	100	—
Birds transferred to clean cage	0.25	0	0	0	—
	.5	20	0	0	—
	.75	0	0	0	—
	1	40	0	0	—
	2.5	100	100	100	100

[a] 1 day after hand dusting and 3 days after sprinkle dusting.
[b] 8 days after hand dusting and 15 days after sprinkle dusting.

was equally effective at 1%. All the treatments except DDT apparently eradicated mite infestations as the birds were clean after 30 days. However, these birds were not subject to reinfestation pressure from other sources.

In tests with the sprinkle method of application, Bayer L 13/59 was effective at 2.5% but not at 1% 30 days after treatment, whereas Chlorthion was 95% effective at 1% and completely effective at 2.5% after 45 days. The birds remained in the same cage in which they were dusted and thus, theoretically, were subject to contact and vapors of the insecticide.

All treatments of 1% or less of malathion were ineffective when the birds were removed from the cage in which they were treated, but some effectiveness was demonstrated when they were allowed to remain in the cage. Dusts of 0.25% malathion failed under both conditions, but 2.5% dusts gave control. Birds removed to clean cages probably lost some of the powder before being transferred. A reduction in the amount of insecticide on the birds would in turn be expected to reduce the kill of mites by either contact or fumigation. Individual birds sprayed with 25 ml. of 0.25, 0.5, or 1% malathion were freed of mites through 30 days of observation.

In tests with hens infested with lice 0.5% and higher concentrations of malathion applied by the sprinkle technique gave complete control of both species for 30 days. Malathion at 0.25% was relatively ineffective.

Flock Treatments.—Results of the flock treatments against the fowl mite are summarized in table 2. One per cent malathion applied with a pump-gun duster to flocks on wire was ineffective, whereas 5% dusts gave complete immediate control of mites and were 70% effective after 28 days. However, the dust gun used (Chapin Model 119) had a very low output per stroke and was not well adapted for large-scale dusting.

One flock of old hens treated with 5 grams of 2.5% malathion by the sprinkle-dusting method showed excellent control for at least 60 days. A flock of younger birds treated with 3 grams of 5% malathion exhibited no active

Table 2.—Control of the northern fowl mite with malathion on flocks of white leghorn hens confined in colony-type wire cages.

Per Cent Concentration	Grams per Bird	Number of Birds	Degree of Infestation	Per Cent Control After—(Days)				
				7	14	21	28	60
			With Pump-gun Duster					
1	1.5	123	Heavy	20	10	0	—	—
5	3	120	Moderate	100	100	—	70	—
			Sprinkle Dusting					
5	3	34	Moderate	100	100	—	60	—
2.5	5	91	Heavy	100	100	100	100	100
			With Rotary Duster					
2.5	5	129	Moderate	100	100	100	100	—
	3	1600	Moderate	90[a]	90	80	50	—
		180	Heavy	50	50	30	—	—
4	3	380	Light	99	100	100	100	100
		640	Heavy	90	90	75	60	—
		285	Heavy	80	95	—[b]	—	—
	4	250	Moderate	95	99	100	100	—
	5	1000	Heavy	100	100	100	100	—
	4	425	Light	100	99	95	—[c]	—
		2000	Moderate	99	100	100	100	95
		145	Light	97	99	93	80	—
		585	Heavy	94	98	—	65	—
			Flock Spraying					
0.25	25 ml.	200	Moderate	100	100	95	85	—
.5	25 ml.	800	Light	100	100	100	100	100
		400	Moderate	100[a]	100	100	100	—

[a] Same control after 3 days.
[b] Flock moved.
[c] Pullets added to laying house, test stopped

Table 3.—Results of treating litter with 4% malathion dust for control of the northern fowl mite on white leghorn hens.[a]

Square Feet Treated		Degree of Infestation	Per Cent Control After (Days)			
With 1 Pound	Total		7	14	21	42
200	1000	Moderate	80	60	20	—
	960	Light	100	100	100	100
100	1200	Moderate	95	100	100	97
	1000	Moderate	100	100	100	100
50	950[b]	Heavy	98	85	30	—
	900	Moderate	100	99	95	95
40	1000	Light	95	100	100	100
	500[b]	Moderate	—	100	100	100
0	None	Light		No control		

[a] Except where otherwise indicated, 350 birds exposed to each treatment.
[b] 250 birds.

mites after 14 days but was infested again after 28 days.

Treatment of flocks on wire with a rotary duster was found to be a rapid, simple method of application. The average dusting time was approximately 30 minutes per thousand birds. Although the dust was applied at rates of 1.5 to 5 grams per bird, only small fractions of these amounts adhered to the birds. High initial control of mites was obtained in all except one of 11 flocks given this treatment. This was a heavily infested flock treated with 3 grams of 2.5% dust per bird. The degree of control beyond 21 days was variable. Flocks having a light pretreatment infestation generally remained free of mites longer than those having a heavy infestation. The pressure of reinfestation and the condition of the birds' feathers (dense or open) undoubtedly contributed to the variability. In general, however, the results indicated that practical control of the northern fowl mite can be obtained for at least 30 days by applying a 4% malathion dust at the rate of 4 grams per bird.

Although only three spray tests were completed on flocks on wire, excellent initial and residual control was obtained with 0.5% malathion applied at the rate of 25 ml. per bird. In one test with 0.25% malathion, light infestations were observed after 21 days.

Litter Treatments.—Results of tests of litter treatments for the control of mites are presented in table 3. The infestation on birds was reduced 80 to 100% during the first week following the application of 4% malathion. Thereafter the population appeared to reflect the pretreatment density. One pound of the dust to 200 square feet apparently eliminated mites in a lightly infested flock, but the same treatment on 50 square feet in heavily infested flocks was not so effective.

Results of applications of various dusts to litter for the control of lice are presented in table 4. One per cent lindane and 4% malathion at the rate of 1 pound of dust per 150 square feet gave complete control through at least 21 days. Chlorthion at 4% was effective through 7 days, but a few live lice were found thereafter. DDT at 1 pound to 150 square feet was ineffective and at 1 pound to 75 square feet gave only partial control.

Table 4.—Results of applications of various dusts to litter for the control of lice.[a]

Insecticide[b]	Square Feet Treated with 1 Pound	Per Cent Control After (Days)		
		7	14	21
Lindane	150	100	100	100
Chlorthion	150	100	80	80
Malathion	150	100	100	100
DDT	150	0	0	0
	75	60	75	70

[a] Each treatment given to 150 heavily infested birds over an area of 775 square feet.
[b] Lindane at 1 per cent, all others at 4 per cent.

Summary.—Control of the northern fowl mite (*Bdellonyssus sylviarum* (C. & F.)) on white leghorn hens was effected in the laboratory by hand-dusting with 1% of lindane and 5% of lauseto neu, Bayer 21/199, Bayer L 13/59, Am. Cyanamid 4124, Chlorthion, and malathion. DDT was ineffective at 5%. Bayer L 13/59, Chlorthion, and malathion also gave good control when a 2.5% dust was sprinkled over the backs of the birds.

Dusts containing 0.5% or more of malathion gave complete control of the body louse (*Menacanthus stramineus* (Nitz.)) and the shaft louse (*Menopon gallinae* (L.)) on birds held in individual cages, but a 0.25% dust was less effective.

A 4% malathion dust applied with a rotary duster to flocks on wire at a rate of 4 grams per bird gave practical control of the fowl mite for at least 30 days.

Malathion as an emulsion spray at 0.25–0.5%, 25 ml. per bird, gave good control of the fowl mite in field tests.

Litter treatments of malathion dusts for mite control were 80 to 100% effective initially when 1 pound of 4% dust was applied to floor areas of 40 to 200 square feet. However, its residual effectiveness was erratic and only the highest rate could be considered an effective one-application treatment. Dusts of lindane at 1% and malathion at 4% were completely effective against lice when applied at 1 pound per 150 square feet. A 4% Chlorthion dust was slightly less effective and DDT gave no control at 150 and only partial control at 1 pound to 75 square feet.

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Responses of Apple Trees to Mite Infestations: II[1]

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Studies were started by the writers in 1951 to measure the effects of infestations of the European red mite, *Metatetranychus ulmi* (Koch), the two-spotted spider mite, *Tetranychus telarius* (L.,) and possibly of other species on the growth and fruitfulness of apple trees. Two young orchards were selected for the investigation. In these, through the use of acaricidal treatments, mite infestations were kept at a low level in half of the trees but were left uncontrolled in the remaining half. Records obtained the first year have been reported (Chapman *et al.* 1952). The present paper presents the data obtained the second season, or in 1952.

The plot layouts established in the two test orchards in 1951 were continued without change into 1952. As in 1951, the owners applied a full series of insecticide-fungicide treatments to the blocks but endeavored to omit materials that had acaricidal action. In the Nesbitt orchard, however, a fungicidal spray mixture was applied during the blossom period that virtually eliminated the European red mite population present. This treatment contained a mixture of an organic mercury fungicide (Tag) and glyodin. Subsequent studies (Lienk & Chapman 1953) have shown that both of these fungicides are toxic to mites and may be effective acaricides under some conditions as in the present where the mite population was limited to the susceptible early stages. In any event, what promised to be a normal European red mite infestation based on the number of winter eggs present failed to materialize. A mite population did develop here eventually but it occurred late in the growing season and was largely limited to the two-spotted spider mite. No interfering pesticides were applied by the grower in the Wilson block. A moderate infestation of the European red mite developed here and reached peak activity around July 5 to 15 which is about normal for this area. Mite population records on the two test orchards are given in table 1. A comparison of the mite populations in the Cortland trees of the Nesbitt orchard in 1951 and 1952 is shown in figure 1. Essentially, it was a European red mite infestation the first year and a two -spotted spider mite culture the second year.

Two acaricidal sprays were applied to the trees in each orchard that we wished to keep free of infestation. The first was applied in the Wilson planting on May 29 and consisted of 50% ovex, 1 pound of wettable powder and TEPP, ⅓ pint of 20% formulation in 100 gallons of water. Owing to the later appearance of a sizeable number of mites in the Nesbitt orchard the first treatment was delayed until June 20. The spray formulation used then per 100 gallons was: Aramite 15% 1½ pounds of wettable powder and TEPP, ⅓ pint of 20% formulation. Both plantings received a second acaricidal spray on August 6. It consisted of Aramite, 1½ pounds in 100 gallons.

Experimental Results.—The most striking response to mite activity noted in 1952 was the difference in the amount of bloom produced by the Cortland trees of the Nesbitt orchard. It was much lighter in trees where mites had not been controlled. This result is to be charged to an interference by the mites with the process of fruit bud differentiation in 1951. Since fruit buds are believed to be formed in early summer this process must have coincided rather closely with the period of maximum feeding of the European red mite (Fig. 1), or in late June and early July.

Table 1.—Mite population levels in the two mite-untreated blocks in 1952.

Orchard	Variety	Hatched Mites per Leaf on Dates Sampled				
		5/29	6/18	7/8	8/4	9/8
Nesbitt	Cortland	—	7	12	13	39
	R. Delicious	—	9	6	31	125
Wilson Bros.	Macoun	4	10	28	5	—
	Rome	6	16	71	6	—
	R. Delicious	8	37	121	10	—

The bloom was sufficiently sparse on all Cortland trees in 1952 that it was feasible to count all of the blossom clusters present. This was done and with these results:

Ave. no. blossom clusters

47 mite-free trees	*47 mite-infested trees*
343	86

The foregoing record shows that mite activity in 1951 caused a 75.0% reduction in the number of fruit buds formed that year. It should be appreciated that these trees had a heavy blossom and, for their age, bore a heavy crop in 1951. While the Cortland variety tends to annual fruit production it was expected in line with the foregoing observation that the blossom and crop would be lighter in 1952. This proved to be the case but the differences found between mite-free and mite-injured trees was not anticipated.

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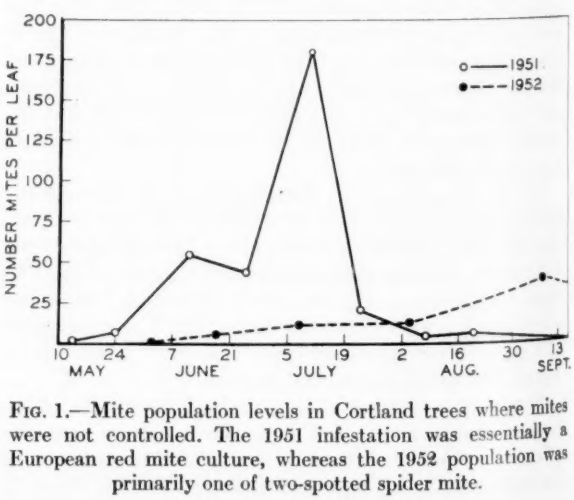

Fig. 1.—Mite population levels in Cortland trees where mites were not controlled. The 1951 infestation was essentially a European red mite culture, whereas the 1952 population was primarily one of two-spotted spider mite.

Table 2.—Blossom records of the Red Delicious variety in the Nesbitt orchard, 1951–1952.

1951 Status			Per Cent Trees in Bloom Classes, 1952[a]				Mean 1952 Bloom Factor[b]
Bloom	Mites	No. Trees	Very light	Light	Medium	Heavy	
Light	Controlled	18	0	0	0	100	7.9
	Not controlled	14	0	0	14	86	7.6
Medium	Controlled	18	0	0	11	89	7.5
	Not controlled	22	0	5	50	45	6.3
Full	Controlled	22	32	18	36	14	4.1
	Not controlled	20	55	30	10	5	2.7
Average	Controlled	58	12	7	17	64	6.4
	Not controlled	56	20	12	27	41	5.4

[a] Based on blossom classes of 1951.
[b] Each tree was graded using a scale ranging from 0 = no bloom, to 8 = full bloom.

Almost all of the effects noted in the Nesbitt orchard in 1952 can be attributed to mite activity in 1951. Whether the 1952 population had been large or small it obviously could have had no influence on the amount of bloom which occurred since this was more or less predetermined the previous season. As shown in figure 1, the 1952 mite population was at a low level throughout most of the growing season. Appearing as late as it did the relatively light two-spotted spider mite infestation is believed to have had little or no influence on the harvest record. In support of this contention attention is directed to the data on fruit size in tables 3 and 4. Any appreciable late season effect would ordinarily be evident in fruit size. As can be seen no significant differences in size were found between the fruits from mite-free and mite-injured trees.

A response similar to that noted for Cortland also occurred in the Red Delicious trees of the Nesbitt block. The results were less striking and were also complicated by the tendency of this variety to be biennial in bearing. When the experiment was initiated in 1951 the Red Delicious trees ranged widely in bloom and crop status. They could be roughly grouped into three bloom (crop) classes, viz., light, medium, and full. The blossom situation in these trees for the two seasons is given in table 2. The part of this record that is more or less directly comparable with the Cortland data is the group of 42 trees that had a full bloom and crop in 1951. Using the bloom factor values of 4.1 and 2.7 given for mite controlled and not controlled trees, respectively, we see that mite activity apparently reduced fruit bud formation in Red Delicious in the Nesbitt block approximately 34 per cent in 1951.

Harvest and growth records are given in tables 3 and 4 for the trees in the Nesbitt orchard and in tables 5 and 6 for the Wilson planting. No yield records were obtained from the Macoun variety in either 1951 or 1952.

Cortland trees in the Nesbitt orchard in which mites had not been controlled produced 61.7% fewer fruits and 64.8 fewer bushels in 1952 than the trees where mites

Fig. 3.—Yield and fruit size in 1952 of Cortland apple trees where mites were controlled and not controlled, Nesbitt orchard, Albion, N. Y.

Mite Status	Range in Initial Trunk Girth (Inches)	No. Trees Observed	Yield in Fruits		Average No. Picked Fruit per Bushel	Yield in Bushels	
			Average No. per Tree	Per Cent Reduction		Average Bu. per Tree	Per Cent Reduction
Controlled	8–13.9	9	165	—	121	1.7	—
Not controlled	8–13.9	11	72	56.3	97	0.7	58.8
Controlled	14–15.9	10	347	—	96	3.6	—
Not controlled	14–15.9	13	154	55.6	94	1.6	55.5
Controlled	16–17.9	17	370	—	94	3.9	—
Not controlled	16–17.9	15	119	67.8	105	1.1	71.7
Controlled	18–21	11	451	—	88	5.1	—
Not controlled	18–21	8	202	55.2	94	2.1	58.6
Controlled	Average	47	345	—	92	3.7	—
Not controlled	Average	47	132	61.7[a]	96	1.3	64.8[a]

[a] Significant at 1% level.

Table 4.—Yield and fruit size in 1952 of Red Delicious apple trees bearing 5 bushels or more in 1951, where mites were controlled and not controlled, Nesbitt orchard, Albion, N. Y.

Mite Status	Range in Initial Trunk Girth (Inches)	No. Trees Observed	Yield in Fruits		Average No. Picked Fruit per Bushel	Yield in Bushels	
			Average No. per Tree	Per Cent Reduction		Average bu. per Tree	Per Cent Reduction
Controlled	14–16.9	7	474	—	138	3.4	—
Not controlled	14–16.9	7	389	17.9	132	2.9	14.7
Controlled	17–17.9	6	556	—	128	4.3	—
Not controlled	17–17.9	6	189	66.0	118	1.6	62.7
Controlled	18–21	10	514	—	101	4.0	—
Not controlled	18–21	8	370	28.0	122	2.9	27.5
Controlled	Average	23	512	—	130	3.9	—
Not controlled	Average	21	324	36.7[a]	127	2.5	35.8[a]

[a] Significant at the 5% level.

Table 5.—Yield and fruit size in 1952 of Rome apple trees where mites were controlled and not controlled, Wilson Bros. orchard, Waterport, N. Y.

Mite Status	Range in Initial Trunk Girth (Inches)	No. Trees Observed	Yield in Fruits		Average No. Picked Fruit per Bushel	Yield in Bushels	
			Average No. per Tree	Per Cent Reduction		Average Bu. per Tree	Per Cent Reduction
Controlled	12–15.9	13	155	—	113	1.3	—
Not controlled	12–15.9	13	196	+26.4	121	1.6	+23
Controlled	16–17.9	15	296	—	119	2.4	—
Not controlled	16–17.9	18	406	+37.1	118	3.4	+41.6
Controlled	18–21	5	979	—	128	7.6	—
Not controlled	18–21	7	146	85.0	104	1.4	81.5
Controlled	Average	33	344	—	121	2.8	—
Not controlled	Average	38	286	16.8	117	2.4	14.2

were controlled. As previously noted this reduction is chargeable to the 1951 infestation. No significant differences were found in fruit size and in growth expressed by trunk girth measurements between the two tree classes. Since the moderate mite infestation that did occur reached its peak in September when growth is essentially completed for the season it is not surprising to find that the rate of growth was about the same in mite-free and mite-uncontrolled trees.

Using the Red Delicious trees of the Nesbitt planting that produced 5 bushels or more in 1951, a response similar to that found for Cortland was noted. Thus, the mite feeding of 1951 reduced the crop in 1952 by 36.7% in number of fruits and 35.8% in bushels.

Moderate crop reductions were caused by 1952 mite infestations in the Wilson block. However, this orchard has been a disappointment. Some unfavorable soil condition apparently exists in about half of the block for the trees have made a poor growth here and the over-all growth and fruiting pattern has been very uneven. This situation was not corrected through nitrogen fertilization.

Samples of leaves were collected for chlorophyll determination on July 24 and September 25. Mite feeding caused a definite reduction in leaf chlorophyll and was of the order of ±30% ultimately in both 1951 and 1952. The records obtained are given in table 7. Because of the low mite incidence little difference was found between the mite-controlled and uncontrolled trees on July 24 in the Nesbitt block but by September 25 the mites had lowered the chlorophyll content almost 30% or to a point comparable to that of the Red Delicious in the Wilson orchard.

Special Observation.—Economic losses that may be caused by orchard mites under conditions prevailing in this area are well illustrated in the record obtained in the Cortland variety of the Nesbitt orchard. Here it was possible to measure the effects of a single infestation of the European red mite on the crops produced in two seasons. The essential facts are presented in table 8. As will be seen, the material here is expressed on an acre basis and further, the Cortland trees are assumed to have been planted in a solid block. It is of special interest to note that while the single infestation of mites caused the considerable reduction in yield shown here, there was little visible indication of damage. In 1951 the leaves of the mite-infested trees were lighter in color but this difference might not have been evident to a casual observer. (Leaf injury was clearly evident in the untreated Red Delicious, but as just stated, injury in the Cortland variety consisted only of a rather uniform paling of the leaves.) There was virtually no leaf drop in any of the trees and no differences were noted between mite-free and mite-injured trees in the amount of leaf drop, in

Table 6.—Yield and fruit size in 1952 of Red Delicious apple trees where mites were controlled and not controlled, Wilson Bros. orchard, Waterport, N. Y.

Mite Status	Range in Initial Trunk Girth (Inches)	No. Trees Observed	Yield in Fruits		Average No. Picked Fruit per Bushel	Yield in Bushels	
			Average No. per Tree	Per Cent Reduction		Average Bu. per Tree	Per Cent Reduction
Controlled	11–12.9	20	295	—	130	2.2	—
Not controlled	11–12.9	15	111	62.3	124	0.8	63.6
Controlled	13–14.9	22	268	—	132	2.0	—
Not controlled	13–14.9	22	167	37.6	114	1.4	30.0
Controlled	15–15.9	11	402	—	143	2.8	—
Not controlled	15–15.9	19	370	7.9	137	2.7	3.5
Controlled	16–18	19	526	—	131	4.0	—
Not controlled	16–18	17	398	24.3	141	2.8	30.0
Controlled	Average	72	362	—	133	2.7	—
Not controlled	Average	73	260	28.1[a]	132	1.9	29.6[a]

[a] Significant at the 5% level.

Table 7.—Chlorophyll content[a] of leaves injured by mites in 1952.

	July 24		Sept. 25	
	Spur	Shoot	Spur	Shoot
Delicious, Wilson Orchard				
Control	3.0	3.4	2.7	3.0
Mite-injured	2.4	2.7	1.8	2.1
Per cent reduction	20[c]	21[c]	33[c]	30[c]
Delicious, Nesbitt Orchard				
Control	3.9	3.8	3.6	3.9
Mite-injured	3.5	3.3	2.3	2.7
Per cent reduction	10[b]	12	36[c]	30[c]
Cortland, Nesbitt Orchard				
Control	2.9	2.5	2.6	2.7
Mite-injured	2.9	2.4	1.9	1.9
Per cent reduction	0	4	27[c]	29[c]

[a] Expressed as mg. per 100 sq. cm. of leaf area. A one-cm.^{2} disk cut from 24 leaves on a tree. Eight to twelve trees sampled or each entry.
[b] Significant at 5% level.
[c] Significant at 1% level.

harvest fruit-drop or in the size of harvested fruit.

SUMMARY.—To measure the nature of injury to apple trees by the European red mite, *Metatetranychus ulmi*, and the two-spotted spider mite, *Tetranychus telarius*, populations were kept at a low level in half of the trees in two young orchards and were left uncontrolled in the remaining half. This paper reports the results obtained the second year of the investigation, or in 1952. The mite infestation of 1951 apparently had a pronounced effect on fruit bud formation in the Nesbitt orchard. Bloom here was 75% lighter in mite-injured Cortland trees in 1952 and 34% lighter in comparable trees of the Red Delicious variety. Yields in bushels of apples at harvest for the two varieties were 64.8% and 35.8% lower, respectively. This reduction was caused almost exclusively by the European red mite infestation of 1951 for no appreciable mite population occurred in the Nesbitt planting in 1952 until late August and September, and this was a culture of the two-spotted spider mite.

Lower yields were also obtained in mite infested trees of the Wilson block. The reduction of 29.6% for Red Delicious was significant but that for Rome of 14.2% was not.

No appreciable difference in growth, based on trunk girth measurements, was found in either test orchard in 1952 between mite-free and mite-injured trees. This result is attributed to a light mite infestation and poor growing conditions in the Wilson block and to the very light mite population during most of the growing season in the Nesbitt block.

Table 8.—Effect of a 1951 infestation of European red mite on the per acre yield in the Cortland variety, Nesbitt orchard, for 1951 and 1952.

Tree Class	Yield in Bushels per Acre (109 Trees[a])[b]		
	1951	1952	2-Year Total
Mite-free	861	403	1264
Mite-injured	621	142	763
Difference	240	261	501

[a] Planted 20 × 20 ft.
[b] For 1951 data see Chapman *et al.* (1952), Table 3, and present paper, Table 3, for 1952 record.

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NOTICE TO MEMBERS

See Program Highlights on page 5 of the June 1956 Bulletin of the Entomological Society of America. The deadline for receipt of titles and abstracts of papers to be presented at the Annual Meeting in New York in December is September 1, 1956. Send to P. W. Oman, Chairman of the Program Committee Entomology Research Branch, Beltsville, Md.

Practical Application of Chemical Controls of Root Maggots in Rutabagas[1]

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The 1954 experiments reported here were designed mainly to test field-scale methods of applying treatments which, each year since 1951, had proved effective against root maggots in rutabagas (swede turnips) when applied by hand methods (King & Forbes 1954, King *et al.* 1955). Results obtained by commercial growers using these treatments were also observed. The cabbage maggot, *Hylemya brassicae* (Bouché), was the chief species in these tests. In all instances the attack was so severe that commerical production of table rutabagas was impossible where adequate control measures were not used.

Of outstanding effectiveness and suitability for grower use in previous years' work, already cited, were two insecticides, heptachlor and aldrin, and three methods of application, the spray method, the band method, and the furrow method. In the spray method, two spray applications are made to the crowns of the plants and adjacent soil surface. The first application is made about 2 weeks after seeding and the second 4 or 5 weeks later. In the band method, the insecticide, as a dust, is placed in a 10-inch band centered along the future crop row. The top inch of soil is immediately raked and the row is than seeded. In the furrow method, the insecticide, as a dust, is placed in the furrow with the seed.

Field Experiments.—Essentially identical experiments, each of five randomized blocks, were carried out at Victoria and Courtenay, British Columbia. Field-scale methods of applying the spray and band treatments with heptachlor were compared with the hand methods of applying the same treatments. Hand methods of applying the spray and band treatments with aldrin and the furrow treatments with both heptachlor and aldrin were also included, making a total of eight treatments and a check for the experiments.

The field-scale treatments were applied by means of a fertilizer cart and a two-row power sprayer, respectively. As in previous work, the hand treatments were made with an improvised shaker for the dusts and a bucket-pump sprayer for the sprays.

Rates for the band, spray, and furrow methods were 5, 5, and 2.5 pounds of toxicant per acre for aldrin, and 5, 3, and 2.5 pounds for heptachlor, the rows being 3 feet apart. All sprays were applied at 200 gallons per acre. Formulation used, rate, and method application for each treatment are shown in table 1.

A practical plot lay-out was worked out by which it was possible to compare statistically, in a single analysis of variance, data obtained from the small plots treated by hand methods with those obtained in the same experimental field from the much larger plots treated by field-scale methods. The two field-scale methods of treatment were duplicated on strips running the length of the field, each strip containing two 250-foot rows. For the power-spray treatment there was a buffer row on either side of the sprayed strip to minimize contamination of adjacent plots due to spray drift. The locations of these strips within the field, the sections of them chosen for sampling purposes, and the placement of the hand-treated plots were all determined by the use of random number tables. Each hand-treated plot consisted of 50 feet of rutabaga row. Each experiment, including buffer areas on either side and end, consisted of about ½ acre of rutabagas. All buffer rows, and buffer sections at the row ends, were given the aldrin band treatment.

Appraisal of the treatments was made mainly at harvest, when the amount of maggot injury on 40 roots from each plot was determined and expressed as a damage index (King & Forbes 1954). Yield of marketable rutabagas was determined at the same time.

Growers' Tests.—Several growers on Vancouver Island in 1954 treated a considerable acreage of rutabagas with aldrin using a power sprayer (spray method) or a fertilizer cart (band method). In the instances reported below, assistance was given them only in calibrating the equipment used to apply recommended rates. These growers co-operated in leaving small untreated sections in their fields to serve as checks. Appraisal of results was made by us at harvest.

Results and Discussion.—Results of the experiments are shown in table 1. The spray treatments, both aldrin and heptachlor, gave rutabagas almost all free from any material damage by maggots. The furrow treatments gave at least 90% reduction in damage; the band treatments also gave good commercial control.

All the treatments greatly increased the yield of marketable rutabagas (Table 1). Increases over the check ranged from 6 to 10.5 tons per acre at Victoria and 15 to 25 tons per acre at Courtenay, averaging 7.6 and 20 tons per acre, respectively. Total yields from the various plots ranged from 12 to 16.6 tons per acre at Victoria and from 24.5 to 31.9 tons per acre at Courtenay, averaging 13.8 and 28.6 tons per acre, respectively. The check plots at Victoria and Courtenay yielded 15.8 and 29.3 tons per acre, respectively. In the total yields there were no significant differences between the check and any of the treatments. Thus, the effect of treatment is not on total yield but rather on marketability.

The field-scale methods of application tested gave results that were not significantly different from those obtained for the same treatment applied by hand methods (Table 2). Important confirmation of the practical effectiveness of the field-scale methods of application was afforded by the growers' tests (Table 3). Good control was also obtained in all other growers' tests of which we have report, except two. In one of these the failure was clearly attributable to faulty application, the insecticide having been broadcast and worked in several inches deep

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[3] The authors gratefully acknowledge assistance throughout the experiments by M. D. Noble, Technician, and on occasion by A. T. Wilkinson, Assistant Entomologist.

Table 1.—Root maggot damage and control and yields of marketable rutabagas at Victoria and Courtenay, B.C., 1954.

Method and Chemical[a]	Toxicant per Acre[b] (Pounds)	Mean Damage Index[c] Victoria	Mean Damage Index[c] Courtenay	Average Per Cent Control	Tons per Acre Victoria	Tons per Acre Courtenay
Untreated	Nil	59.5	70.0	—	5.0	5.7
Band method						
Aldrin	5	5.5	7.0	90	13.6	24.7
Heptachlor	5	7.5	13.8	84	11.4	24.4
Heptachlor[d]	5	3.2	11.0	80	13.2	20.7
Spray method						
Aldrin	5	2.8	1.8	97	11.4	26.7
Heptachlor	3	2.8	1.0	97	11.5	27.6
Heptachlor[d]	3	4.5	5.0	93	11.0	23.5
Furrow method						
Aldrin	2.5	5.5	7.3	90	15.5	27.7
Heptachlor	2.5	3.1	2.3	96	13.1	30.8
L.S.D. at 5% level		6.7	6.6		2.9	5.6

[a] Band and furrow methods: 2.5% dust. Spray method: emulsifiable concentrate containing 2 pounds of toxicant per gallon. Aldrin supplied by Shell Oil Company of Canada, Toronto, Ontario, and heptachlor by Velsicol Corporation, Chicago, Illinois.
[b] For rows 3 feet apart; for sprays, the total of two applications.
[c] Maximum damage index (King & Forbes 1954), 100.
[d] Field-scale method of application.

instead of being concentrated near the surface and along the row. The other test in which poor control was reported was in muck soil.

The cumulative data for 6 treatments by hand methods in 10 comparable replicated experiments carried out from 1952 to 1954 in 5 localities (Table 4) show that, on the average, heptachlor and aldrin, whether applied by spray, band, or furrow method, afforded outstanding control. The original figures from which this table was derived show a high degree of consistency and represent results obtained under a wide range of seasonal and local conditions. The facts presented in the preceding paragraphs suggest a similar dependability for field-scale methods of application when correctly employed.

These experiments and observations provide basis for the following conclusions:

(1) The band method is practical for a grower with up to 5 acres of rutabagas to treat. In practice, treatment is most easily made with a small calibrated fertilizer cart with attachments to mark the next row and to rake in the insecticide behind the cart.

(2) The spray method is practical for growers with a row-crop sprayer. It is particularly suitable for the treatment of large acreages. The first application must be made immediately after an early thinning, i.e., 2 to 3 weeks after seeding. This is before oviposition has commenced on the plants, since few if any eggs are laid about rutabagas while they are still very small. The second application must be made as late in the season as it is practical to use power spraying equipment without injuring the crop. In practice, this is about 6 to 7 weeks after seeding. Under British Columbia conditions, this is before the important third generation eggs are laid; it is also after the last cultivation of the season. The 200-gallon per acre rate is advisable for the second application to give adequate coverage at a time when the rutabaga roots are large and there is considerable interfering foliage. The results here reported were obtained at spray pressures not exceeding 80 pounds per square inch, and with coarse droplets. Observations indicated that much poorer, and perhaps inadequate, control might result if high pressures and fine mists were employed.

(3) The cost of the insecticides for the band and spray treatments at present-day prices ranges from approximately $11.00 per acre for the heptachlor spray to $24.00 per acre for the aldrin or heptachlor band. The aldrin spray treatment costs $18.00. As compared with band treatments, spray treatments not only are cheapest from the standpoint of cost of materials but also can be more easily and rapidly applied, are somewhat more effective, and are dependable under a wider range of conditions. Against this is the fact that spray treatments involve two applications and the grower must have adequate spraying equipment. For either treatment, the price of one ton of rutabagas more than covers the cost per acre of insecticide. From this fact and the great increase in the marketable yield due to treatment (Table 1) it is clear that anyone growing rutabagas cannot af-

Table 2.—Root maggot control and yields of marketable rutabagas for hand and field-scale methods of applying heptachlor at Victoria and Courtenay, B.C., 1954.

Method of Treatment[a]	Per Cent Control Hand	Per Cent Control Field	Tons per Acre Hand	Tons per Acre Field
Band				
Victoria	87	95	11.4	13.2
Courtenay	80	84	24.4	20.7
Spray				
Victoria	95	92	11.5	11.0
Courtenay	99	93	27.6	23.5
Average	90	91	18.7	17.1

[a] Band 5 lb., spray 3 lb. (total, in 2 applications), of toxicant per acre for rows 3 feet apart.

Table 3.—Percentages of marketable rutabagas obtained with aldrin applied by field-scale methods in growers' tests (4 fields) on Vancouver Island, B.C., 1954.

Method and Locality	Untreated	Treated
Band[a]		
Courtenay	0	89
Honeymoon Bay	low[b]	89
Honeymoon Bay	10	88
Spray[c]		
Honeymoon Bay	low[b]	92

[a] Five pounds of toxicant per acre for rows 3 feet apart.
[b] Untreated early plantings in these fields were completely destroyed by root maggots. Sections of later plantings left for checks were mistakenly given a single late spraying with aldrin (2.5 pounds of toxicant per acre) but still gave less than 30% marketable rutabagas. It was estimated that fewer than 10% marketable roots would have been produced had no spray been applied.
[c] Five pounds of toxicant per acre (total, in 2 applications).

Table 4.—Average percentages of reduction in damage to rutabagas for hand treatments for five localities.[a]

Chemical	Band[b]	Spray[c]	Furrow[d]
Aldrin	84	92	86
Heptachlor	90	93	92

[a] Victoria, Courtenay, Agassiz, and Kelowna, B.C., and Puyallup, Washington (King *et al.* 1955). One to three seasons at each (10 fields).
[b] Five pounds of toxicant per acre for rows 3 feet apart.
[c] Aldrin, 5 pounds per acre; heptachlor, 3 pounds per acre; total of two applications.
[d] Two and five-tenths pounds per acre.

ford to omit control measures wherever root maggots are pests.

(4) The recommendation for control of root maggots in rutabagas in British Columbia is at present stated as follows (British Columbia and Canada Departments of Agriculture 1955): "Spray the rows with 3 pints of heptachlor emulsion (2 lb. actual per gal.) or 5 pints of aldrin emulsion (2 lb. actual per gal.) per 100 gal. of water. Make two applications each at the rate of 13 gal. dilute spray per 1000 ft. of row; the first application about two weeks after seeding, the second application six to seven weeks after seeding. Or apply 2½% aldrin dust or 2½% heptachlor dust in a 10-in. band at 13 lb. per 1000 ft. of row; rake in not more than 1 in. and sow seed down center of treated area. (Note.—Broadcasting the chemical at the above rate will not give control of maggot.)"

(5) Furrow treatments, though effective, have not yet been recommended for grower use because of the danger of phytotoxicity (King & Forbes 1954, King *et al.* 1955).

SUMMARY.—Experiments in 1954 on chemical control of root maggots in rutabagas showed that field-scale methods of treatment, when properly applied, afford the same high degree of effectiveness as do the more precise, small plot, hand methods. These experiments also confirmed and extended previous findings that highly effective and economical control of root maggots in rutabagas is readily achieved with heptachlor or aldrin applied at adequate rates by band, spray, or furrow methods. Recommendations based on several years' experiments are stated, and some results typical of those obtained by commercial growers who followed them are cited.

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Control of the Southern Garden Leafhopper, A New Pest of Cotton in Southern California[1]

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Leafhopper species of the genus *Empoasca* are recorded as pests of cotton in many parts of the world. Poos & Wheeler (1943) in reviewing the literature listed at least 10 species as seriously damaging this crop in foreign countries. In the United States several species of this genus are recorded as occurring on cotton. *Empoasca fabae*, which occurs in limited areas of the San Joaquin Valley of California, has at times caused serious injury to cotton plants. In general, however, leafhoppers have not been regarded as serious pests of cotton until recently.

The southern garden leafhopper, *Empoasca solana*, was described by DeLong (1931) from potato in Louisiana. The published host list of this insect is extensive and includes a number of important agricultural crops. Poos & Wheeler (1943) reported that an abundance of *E. solana* was noted on cotton in Louisiana in 1937. These authors concluded that this species feeds on the phloem tissue of its various host plants. This conclusion was amply supported by the diseaselike symptoms, usually manifested as wilting or as leaf reddening or yellowing and commonly called "hopperburn," caused by the feeding of this species. Hopperburn has been reported by Carter (1936) on potato, watermelon, and castor bean plants; by Beaumont (1940) on bean plants; and by Martin & Pemberton (1942) on lettuce.

Plant injury caused by *E. solana* is similar to that cuased by *E. fabae* (Harr.), long known as a phloem-feeding species, which causes hopperburn symptoms on many crops. Typical injury resulting from feeding on the phloem tissue by *E. solana* and *E. fabae* was contrasted by Smith & Poos (1931) with the less injurious "stippling" effect on leaves caused by *Empoasca* species which feed primarily on the mesophyll tissue.

The first cotton field observed to be seriously injured by *E. solana* in California was discovered in the Imperial Valley of southern California in July, 1952. Only a few fields developed leafhopper populations large enough to cause injury at that time, but during the following season of 1953 a number of fields sustained injury or received insecticide treatments in order to prevent injury. Surveys undertaken to study the distribution of this pest revealed tremendous populations of *E. solana* in many fields of sugar beets. Apparently, this species builds up to enormous numbers on sugar beet plants, and when this crop is harvested or becomes unattractive to the leafhoppers, they migrate to cotton and continue to breed.

When the leafhoppers are abundant on cotton plants, fruiting is severely affected. Squares and small bolls are sloughed off, and larger bolls, which frequently remain on the plant, turn soft and spongy. Hopperburn is in evidence in that the leaves, particularly the margins, turn a yellowish or reddish color and frequently become somewhat thickened or leathery. Wilting had not been observed. To date, *E. solana* has been abundant on cotton

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only during the early growing season. Populations have usually dropped below economic levels during late June or July.

There can be no doubt that leafhoppers caused the damage described in these cotton fields. Lygus bugs are common in California and when abundant can cause severe damage to fruiting cotton plants. Other than the shedding of squares and young bolls there was little similarity in damage caused by the leafhoppers in comparison with that caused by the several species of mirids affecting cotton production. The effects caused by mirids feeding on cotton plants have been amply discussed by a number of writers, notably Ewing & McGarr 1933, King & Cook 1932, and Smith 1942. In addition, populations of mirids were almost entirely absent or far below those which cause damage to cotton plants. Owing to the serious nature of the injury caused by this species of leafhopper, the development of control measures became essential, and the present studies were undertaken.

MATERIALS AND METHODS.—Insecticide tests were conducted in cotton fields located in the Imperial Valley and utilized both phosphate and chlorinated hydrocarbon materials. All insecticide applications in the experiments reported herein were made with ground equipment, although the results obtained with commercial applications made by airplane were closely followed in a number of fields.

In the first test it was not possible to replicate the treatments, but in the two tests made at later dates each treatment was replicated four times. Because of the migration of adult leafhoppers from plot to plot, the various treatments were evaluated in terms of nymphal mortalities only. In these tests the numbers of nymphs on 50 to 80 leaves per treatment were recorded.

RESULTS.—*Test 1.*—On July 9, 1952, sprays and dusts were applied to cotton plants which were about 5 feet tall. As previously noted it was not possible to replicate the treatments in this field. The treated plots were four rows wide, with 40-inch spacing between rows, and as the treatments were applied in a corner of the triangular field, the plots ranged from 300 to 700 feet in length.

Sprays were applied with a sprayer mounted on a small tractor. The spray boom was equipped so that three spray nozzles were directed onto each row of cotton, 1 nozzle spraying directly down onto the top of the cotton row and 2 nozzles on "drops" spraying into each side of the row. Low-volume hollow-cone nozzles were used, and 21 to 22 gallons of liquid were applied per acre.

The 4-row, 8-nozzle duster[2] was mounted on the same tractor and was operated so that there were two dust nozzles per row. Dusts were applied at rates ranging from 27 to 33 pounds per acre.

On July 11 (2 days after treatment) the number of leafhopper nymphs on 50 leaves per treatment was recorded. Results are summarized in table 1.

Although data obtained from a test such as this are not at all conclusive, it appeared that DDT, parathion, and Perthane would give excellent leafhopper reductions when used for control of this pest. From the results obtained, demeton and toxaphene appeared to require further evaluation. The results obtained with dieldrin were rather poor. It was not possible to make counts after July 11 as the grower treated the remainder of his field with DDT dust (with excellent results) and drift over the plots killed the remaining leafhopper populations. During the rest of 1952 most cotton growers who were plagued with this insect treated their fields with DDT, also with excellent results. In 1953, several failures to control with DDT were reported, however, and a number of cotton growers resorted to the use of parathion and, to some extent, malathion. As a result, further experimentation was considered desirable.

Table 1.—Effectiveness of various sprays and dusts applied by ground equipment for control of *Empoasca solana* on cotton (Test No. 1).[a]

MATERIAL	POUNDS TOXICANT PER ACRE	GALLONS OR POUNDS PER ACRE	LEAFHOPPER NYMPHS PER 50 LEAVES
	Spray		
DDT	1.30	21	0
Parathion	0.20	21	1
Perthane	1.30	22	3
Demeton	0.45	22	8
	Dust		
DDT, 10%, + sulfur, 50%	3.1 15.5	31	0
DDT, 5%, + sulfur, 50%	1.35 13.5	27	2
Toxaphene, 10%, + sulfur, 40%	3.3 13.2	33	10
Dieldrin, 2%	0.56	28	32
Check	—	—	57

[a] Materials applied July 9; counts made July 11, 1952.

Test 2.—On June 22, 1954, sprays were applied to cotton plants which were about 18 inches tall. Populations of *E. solana* were abundant in the field, and typical hopperburn symptoms were common. Treatments were applied by means of a ground sprayer.[3] The sprays were applied at a pressure of 60 p.s.i., and two low-volume hollow-cone nozzles were used per row. Each treatment was replicated four times and each replicate or plot was 26 feet wide by 1170 feet long. All except three of the applications were applied on June 22. Because of an increasing breeze, application of these three treatments was postponed until June 25.

Treatments were evaluated on June 25 and on July 1, 7, and 16. The number of leafhopper nymphs on 80 leaves was recorded on each date for each treatment. Results are summarized in table 2.

In this test Perthane gave outstanding control. The residual period of control with Perthane was longer than that with any other material tested, this being the only insecticide which gave results significantly better than the check on July 16 (21 days after treatment). Results obtained with parathion and Diazinon were excellent, although neither material was so effective as Perthane after the initial counts. Contrary to results obtained on other crops, malathion and Chlorthion gave mediocre leafhopper reductions. Observations made after commercial applications by airplane of malathion for control of this pest on cotton indicate that this material will give excellent results. The results obtained with DDT in this

[2] Cropmaster Duster; manufactured by Niagara Spray and Chemical Division, Food Machinery Corporation, Middleport, N. Y.

[3] Yellow Devil Ground Sprayer; Engine Parts Manufacturing Company, Cleveland, Ohio.

Table 2.—Effectiveness of various insecticides applied by ground sprayer for control of *Empoasca solana* on cotton (Test No. 2).

Material	Pounds Toxicant per Acre	Gallons per Acre	Number of Leafhopper Nymphs per 80 Leaves			
			June 25	July 1	July 7	July 16
Parathion[a]	0.42	5.9	2	67	57	180
Parathion[a]	0.20	5.6	10	155	110	235
Diazinon[a]	0.70	6.6	0	25	71	240
Malathion[a]	0.67	6.3	98	538	171	371
Perthane[b]	1.33	6.2	—	15	5	44
Chlorthion[b]	0.60	6.0	—	456	234	246
DDT[b]	1.35	6.3	—	408	101	321
Check	—	—	341	919	184	299
L.S.D. at 5% level			95	263	62	127

[a] Applied on June 22, 1954.
[b] Applied on June 25, 1954.

test are of interest because, in contrast to results obtained in the 1952 test, the results were only moderately good. This partial failure of DDT is in conformity with the results obtained commercially and leads one to suspect the existence of insect resistance to this material.

Test 3.—On July 1, 1954, sprays of four systemic insecticides were applied to cotton plants which were about 18 inches tall. The materials were applied by the same equipment and in a manner similar to that described in test 2. Each treatment was replicated four times, and each replicate or plot was eight rows (about 27 feet) wide by 140 feet long.

Treatments were evaluated on July 7 and 16 by counting the number of leafhopper nymphs on a total of 80 leaves per treatment. Results are summarized in table 3.

In this test there were no significant differences between results obtained with demeton and with Am. Cyanamid 12008 and Am. Cyanamid 12009, although the results obtained with demeton were consistently somewhat superior to the others. The higher dosages of 12008 and 12009 gave better results than the lower ones, but were not significantly better at odds of 19 to 1. Although the results obtained with Pyrozaxon were significantly better than those of the check, they were definitely inferior to those obtained with the other materials tested.

Table 3.—Effectiveness of four systemic insecticides applied by ground sprayer for control of *Empoasca solana* on cotton (Test No. 3).

Material	Ounces of Toxicant per Acre[a]	Number of Leafhopper Nymphs per 80 Leaves	
		July 7	July 16[b]
Demeton	6	0	5
Am. Cyanamid 12008	6	24	17
	12	4	11
Am. Cyanamid 12009	6	13	32
	12	2	12
Pyrazoxon	6	40	65
Check	—	239	115
L.S.D. at 5% level		49	28

[a] All applications made on July 1, 1954 at the rate of 6 gallons per acre.
[b] As the result of a rapidly declining leafhopper population, further counts were not made.

SUMMARY.—A number of leafhopper species of the genus *Empoasca* are recorded as pests of cotton in many parts of the world, but until recently none have been reported as serious pests in the United States. Since 1952, the southern garden leafhopper, *Empoasca solana* DeLong, has been causing injury in an increasing number of cotton fields in the Imperial Valley of California. When abundant, the leafhoppers inhibit fruiting and cause "hopperburn," the leaves, particularly the margins, turning a yellowish or reddish color.

DDT was very effective when used for control of this pest in 1952, but an increasing number of failures were reported in 1953 and 1954. Subsequent insecticide tests with DDT bore out this observation, and insect resistance is suspected.

Of the chlorinated hydrocarbon insecticides tested for control of this pest, Perthane gave the most promising results. Of the phosphate insecticides demeton, parathion, and Diazinon gave excellent results. Malathion and Chlorthion gave only mediocre results in these tests on cotton, but when used for control of this pest on other crops results were very good.

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Toxicity of Widely Used Insecticides to Beneficial Insects in California Cotton and Alfalfa Fields[1]

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The beneficial insects occurring in cotton and alfalfa fields in California are varied and abundant and, together, play an important role in the natural control of pest insects. A soundly devised pest control program should take maximum advantage of this natural control by employing insecticides which are highly effective against the pests for which they are applied and of minimum detriment to the beneficial species present. Ideally, specific insecticides would provide the answer to this need, but few such materials are as yet available. This leaves the alternative of searching for materials among the existing insecticides which approach as closely as possible the ideal of specificity. With this objective in mind, experiments were conducted in California during the summer of 1954 in an attempt to determine the relative toxicities of some of the most widely used insecticides to certain important beneficial insects occurring in cotton and alfalfa fields. Similar studies have been reported in the literature (Newsom & Smith 1949, Campbell & Hutchins 1952), but those studies were conducted in the cotton-growing areas of the southeastern United States under conditions differing greatly from those of the irrigated croplands of California.

Studies of the effects of insecticides on beneficial (entomophagous) insects are complicated by certain factors not ordinarily affecting investigations involving phytophagous species, and these factors must be recognized and carefully considered by the worker when he devises his experiments and interprets his data. The first of these factors involves plot size. Small plots, though relatively easy to obtain, treat, and sample, are not entirely satisfactory because of migration of beneficial species, particularly of the adult forms, between treatments. In addition, there is always a certain amount of insecticide contamination from plot to plot at the time of application. Large plots, on the other hand, are difficult to obtain, and tedious and time-consuming to sample. Furthermore, with large plots it may be impractical from the grower's standpoint to leave correspondingly large untreated areas.

Another important complication in a study of this sort lies in the wide variety of insects being studied. Not only are various species of diverse habits involved, but also different developmental stages of each species are present. No two fields support identical faunas, and thus widely varied information can be expected from a series of experiments.

A third complication in any study involving effects of insecticides on beneficial insects lies in the interpretation of mortality. When insecticides are used against phytophagous species, reduction in abundance of the pests in the treated plots is usually assumed to result from mortality caused by the insecticides. With entomophagous species, a similar assumption cannot be made, for, conceivably, reduction in abundance may come about in several ways: it may be directly due to insecticide-induced mortality; it may be caused indirectly by feeding of the beneficial species on insecticide-affected hosts (Ahmed *et al.* 1954); or it may not be directly related to insecticides at all, but due rather to starvation of beneficial species, where the host species has been eliminated, or to their migration away from such areas.

Experimental Methods.—All the studies discussed in this paper were conducted in the field. They involved a variety of experimental designs, plot sizes, insecticidal materials, application methods, etc., as described below.

Sampling was done by the sweep method, using the University of California standard insect net (handle, 26 inches long; hoop, 15 inches in diameter; Indian-head cloth bag, 24 inches deep). In the cotton tests sweeps were taken through the tops of one row of plants with a back-and-forth movement of the net, each sweep being approximately one step distant from its predecessor. During the sampling of a plot excess trash was periodically removed from the net, and the accumulated sweepings were emptied into bags or cartons and held in an icebox until counts were made. Immediately prior to counting, the samples were fumigated with methyl bromide. Counts were made under bright light with the aid of a head lens. In the alfalfa tests sweeps were taken in pairs of 180-degree arcs, with fewer sweeps per plot than in cotton because of the generally heavier populations of beneficial insects present.

In these experiments only predators were counted, as no satisfactory method has yet been devised to sample adequately the complex of parasites occurring in cotton and alfalfa fields.

Experimental Results.—*Blythe Experiment No. 1.*—This experiment was specifically designed to obtain information on the relative toxicities of a variety of materials and formulations to the predator species. It was conducted in a 40-acre cotton field on the Cal Pro Ranch southwest of Blythe, and involved nine different treatments and a check, there being four randomized replications per treatment. Each replicate or plot was 18 rows wide and 292 feet long. All materials were applied on the morning of July 14, 1954—dusts by broadcast-type ground duster[3] and sprays by a ground sprayer.[4] Samples were taken on July 17, 23, and 30 by the sweep method described above, 100 sweeps being taken from the eighth and tenth rows (50 sweeps per row), beginning 100 feet inside the plot.

The data obtained from this experiment (Table 1) appear to reflect considerable movement of the predators through the plots, for only the July 17 counts show sharp

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[3] Hardie Duster; Hardie Manufacturing Company, Hudson, Michigan.

[4] Yellow Devil Sprayer; Engine Parts Manufacturing Company, Cleveland, Ohio.

Table 1.—Toxicity of various insecticides to important predator species in cotton fields at Blythe, California; July, 1954. Experiment No. 1.

Treatment and Dosage per Acre[a]	Number of Predators per 400 Sweeps in July on Dates Indicated[b]														
	Orius sp.			*Geocoris* sp.			*Nabis* sp.			*Chrysopa* sp.			*Hippodamia* sp.		
	17	23	30	17	23	30	17	23	30	17	23	30	17	23	30
	A-N	A-N	A-N	A-N	A-N	A-N	A-N	A-N	A-N	A-L	A-L	A-L	A-L	A-L	A-L
								Spray							
1. Endrin (0.4 lb.)	66-22	48-40	50-19	7-2	15-2	30-14	8-0	8-4	13-8	1-5	3-3	5-3	58-0	48-0	42-0
2. Dieldrin (0.13 lb.)	77-33	42-61	35-17	16-3	27-7	36-13	14-1	17-5	17-8	8-9	4-11	5-2	82-0	70-0	38-0
3. Parathion (0.27 lb.)	40-6	24-19	40-16	11-7	30-7	55-22	3-1	0-1	7-10	3-2	2-2	6-5	16-0	32-0	33-0
4. Toxaphene (2.85 lb.)	57-29	37-6	35-6	15-3	25-3	50-8	9-1	5-1	7-8	7-2	6-6	12-2	27-0	43-0	36-0
5. DDT (1.35 lb.)	58-34	51-48	31-10	28-10	30-9	37-18	10-1	6-5	15-9	0-5	2-8	7-1	10-0	11-0	37-0
								Dust							
6. 10% Toxaphene (2.6 lb.)+ 50% Sulfur	55-24	35-24	27-15	13-6	28-9	47-17	7-2	1-3	20-9	5-4	2-12	8-1	24-0	26-0	27-0
7. 15% Toxaphene (4.35 lb.)+ 5% DDT (1.45 lb.)+ 40% Sulphur	45-13	52-31	68-20	0-0	33-3	47-5	1-0	3-3	11-3	1-12	3-12	3-1	5-0	13-0	41-0
8. 10% DDT (2.1 lb.)+ 50% Sulfur	87-26	44-51	40-17	42-8	24-6	48-13	5-0	7-4	20-13	0-7	4-11	9-4	20-0	25-1	33-0
9. 5% DDT (1.15 lb.)+ 50% Sulfur	71-33	45-45	17-20	61-11	40-8	47-12	15-1	8-7	13-3	4-11	1-14	3-4	7-0	23-0	31-0
Check	51-55	61-43	11-5	64-29	56-26	85-28	28-1	13-3	14-10	2-9	5-11	9-2	60-0	38-0	26-0

[a] All treatments applied July 14 and replicated four times, except 7 and 9, which were replicated three times and have weight adjusted to four replications.
[b] A–N = adults and nymphs; A–L = adults and larvae.

differences between treatments, the later counts leveling out and showing little difference between treatments. However, the July 17 counts do reflect true differences in toxicity of the various treatments, for these results are substantiated in experiments discussed below.

In this experiment parathion spray and the toxaphene-DDT dust (15% toxaphene, 5% DDT, 40% sulfur) were the most severely toxic treatments. Endrin and toxaphene dusts and sprays, and the heavier dosages of DDT, were next in toxicity. The low dosages of dieldrin and of DDT were the least toxic treatments.

Within these categories the various materials showed wide differences in toxicity to the several beneficial species. To adults of *Hippodamia* sp. endrin was considerably less toxic than DDT and toxaphene, and toxaphene appeared to be somewhat less toxic than DDT. To *Geocoris* sp., on the other hand, DDT was clearly less toxic than either toxaphene or endrin. Among the five predator species, *Orius* (adults and nymphs) and *Chrysopa* (larvae) were the most resistant to the various insecticides. With *Chrysopa* larvae only parathion and toxaphene spray produced substantial reductions below the check, while with *Orius* only parathion and the 15-5-40 dust produced reduction.

The *Orius* counts show an interesting trend in that the numbers of this predator in the check on July 30 were lower than those in any of the treatments. This condition is a possible result of the effect of predation by *Geocoris* sp. on *Orius*, for where the former was severely or even moderately reduced *Orius* maintained its numbers or actually increased in abundance while in the untreated plots *Orius* steadily declined in abundance. Independent observations have shown that *Geocoris* preys on *Orius* to some degree, and the above-mentioned condition in the experimental plots may be an indication that this predation is more extensive than heretofore realized.

Blythe Experiment No. 2.—This experiment was conducted in the same area as Experiment No. 1 and involved several insecticide materials and combinations used for control of the bollworm. The experiment was a large one involving three adjacent fields. Treatments which were applied on the morning of August 5 by airplane were replicated three times, each replicate being approximately 6 acres. Because of the size of the plots, checks could not be obtained, but pre-treatment counts were made. Each replicate was sampled by 150 sweeps taken from the center rows well into the plot. Data are summarized in table 2. Unfortunately, *Orius* and *Hippodamia* counts were low and the plots were difficult to sample because of the extremely tall cotton and the lodged condition of the plants in part of one field. On the other hand, because of the large size of the plots, migration of beneficial species did not occur to the extent that it did in Experiment No. 1, with the result that the counts did not level out after the first sampling date.

In this experiment the toxaphene-DDT combination was clearly the most severe treatment, the dust appearing to be slightly less toxic than the spray. The light DDT-dust application was the least toxic, particularly to *Geocoris*. Endrin spray (at 0.4 pound/acre) appeared to have no toxic effect on *Hippodamia* adults, whereas the dust (at 0.45 pound/acre) appeared to be slightly toxic. Again, as in Experiment No. 1, *Orius* appeared to be little affected by any treatment.

Brawley Experiment.—This experiment was designed to screen a variety of materials as sprays on the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), on alfalfa on the James Smith Ranch east of Brawley. All materials were applied as sprays by a ground sprayer,[4] on July 8, 1954. The small randomized plots (27 feet wide and 225 feet long) were replicated four times, the alfalfa being about 4 to 6 inches high at the time the first sample was taken (July 12). Sweeps were made in pairs at two places in each replicate, the sweepings being bagged, refrigerated, and counted in the laboratory.

Data obtained from this experiment are summarized in table 3 and are particularly interesting because they show the differences in toxicities of the wide variety of materials used. Among these materials, parathion was the most severely toxic, causing significant reductions of *Geocoris*, *Nabis*, and *Hippodamia* spp.; DDT at 1 pound per acre was the least toxic. Toxicity of the various ma-

Table 2.—Toxicity of various bollworm treatments to important predator species in cotton fields at Blythe, California; August, 1954. Experiment No. 2.

Treatment and Dosage per Acre[a]	Number of Predators per 450 Sweeps in August on Dates Indicated[b]									
	Orius sp.		*Geocoris* sp.		*Nabis* sp.		*Chrysopa* sp.		*Hippodamia* sp.	
	12-13	19	12-13	19	12-13	19	12-13	19	12-13	19
	A-N	A-N	A-N	A-N	A-N	A-N	A-L	A-L	A-L	A-L
				Spray						
1. Endrin (0.4 lb.)	16-2	15-1	3-0	2-0	5-1	2-0	12-6	14-2	22-0	16-0
2. Toxaphene (3.0 lb.)+ DDT (1.5 lb.)	18-0	14-0	0-0	1-0	0-0	0-0	0-1	2-8	3-0	3-0
3. DDT (2 lb.)	12-3	8-2	7-0	5-0	4-1	3-2	1-1	3-2	4-0	12-0
				Dust						
4. 1.5% Endrin (0.45 lb.)	16-1	11-5	8-0	7-0	7-2	7-2	6-1	8-4	11-0	20-0
5. 15% Toxaphene (4.5 lb.)+ 5% DDT (1.5 lb.)+ 40% sulfur	29-1	11-1	4-0	3-0	2-0	0-0	6-2	11-8	7-0	10-0
6. 10% DDT (3.0 lb.)+ 50% sulfur	16-1	6-7	5-0	4-1	6-1	7-1	3-4	7-5	13-0	4-0
7. 5% DDT (1.5 lb.)+ 50% sulfur	18-0	8-0	19-5	24-2	10-0	9-3	10-8	6-7	10-0	14-0
Pretreatment, 8/4/54	12-2		33-15		28-6		10-3		19-0	

[a] Applied August 5 by airplane and replicated three times.
[b] A-N = adults and nymphs; A-L = adults and larvae.

terials to *Hippodamia* varied greatly, malathion, parathion, and demeton, being severely toxic to both adults and larvae, while endrin, though apparently nontoxic to adults, was highly toxic to larvae. Toxaphene and DDT at the dosages used were nontoxic to adult *Hippodamia* and only moderately toxic to the larvae. The toxicity shown by demeton parallels the findings of Ahmed *et al.* (1954), who showed that this material caused mortality to coccinellids and syrphids through the feeding of these predators on demeton-affected aphids. As in Blythe Experiment No. 2, no toxicity was shown by any material to *Orius*.

Aphid counts are included in table 3 for two reasons: first, they show that reductions of predators resulted from direct mortality, since in tests with malathion and DDT, where substantial populations remained after treatment, reductions of beneficial insects, particularly of *Hippodamia*, still occurred; and secondly, they show in the July 19 counts that aphid populations were lower in the check than in even the most effective treatments, reflecting the apparent cleanup of aphids by *Hippodamia* where its numbers had not been reduced.

Kern County Experiment No. 1.—This experiment was designed to compare the relative toxicities of commercial dosages of DDT and toxaphene to *Lygus* sp. on alfalfa being grown for seed production. Because of the large plot size (approximately 10 acres) each treatment was replicated only twice. Materials were applied by airplane in alternate plots of 10% toxaphene dust and 5% DDT dust, both at the rate of 35 pounds per acre. No checks were maintained and no pretreatment counts were taken.

Posttreatment counts taken July 1, 8, 14, and 21 are summarized in table 4. Although of limited value because of the lack of pretreatment counts and checks, the data seem to indicate that toxaphene at the dosage used had a somewhat more severe effect than DDT on *Orius*, *Geocoris*, and *Nabis*. There was no difference in toxicity to *Chrysopa* larvae. The apparent differential effect on *Orius* is of interest because it is in contradiction

Table 3.—Toxicity of various treatments applied for control of *Therioaphis maculata* to important predator species on alfalfa grown for hay at Brawley, California; July, 1954.

Treatment and Dosage per Acre[a]	Number of Predators per 16 Sweeps in July on Dates Indicated[b]								No. of *T. maculata* per 100 Alfalfa Stems	
	Orius sp.		*Geocoris* sp.		*Nabis* sp.		*Hippodamia* sp.			
	12	19	12	19	12	19	12	19		
	A-N	A-N	A-N	A-N	A-N	A-N	A-L	A-L	July 12	July 19
1. Malathion (0.71 lb.)	114-0	144-54	16-10	22-8	13-6	11-3	40-5	193-32	1215	1447
2. Parathion (0.2 lb.)	157-0	104-60	10-2	16-13	14-6	6-2	82-18	82-75	389	535
3. Demeton (0.2 lb.)	126-1	91-82	17-4	14-11	18-13	8-1	94-7	99-40	152	467
4. Endrin (0.24 lb.)	165-5	118-101	6-1	20-0	29-19	11-2	156-89	82-50	445	405
5. Toxaphene (2.36 lb.)	122-3	135-87	9-0	17-1	14-18	8-10	161-137	104-59	400	380
6. DDT (1.2 lb.)	158-1	122-140	15-5	25-3	13-21	11-0	156-169	185-102	2024	172
Check	150-11	104-73	18-11	31-25	40-8	10-2	173-403	130-122	5226	126

[a] Applied July 8 and Replicated four times.
[b] A-N = adults and nymphs; A-L = adults and larvae.

Table 4.—Toxicity of commercial airplane applications of toxaphene and DDT dusts to important predator species on alfalfa grown for seed in Kern County, California; 1954.

Treatment[a] and Dosage per Acre	Sampling Date (July)	Number of Predators per 100 Sweeps[b]									
		Orius sp.		*Geocoris* sp.		*Nabis* sp.		*Chrysopa* sp.		*Hippodamia* sp.	
		A	N	A	N	A	N	A	L	A	L
Experiment No. 1 (treatment applied June 27)											
Toxaphene (3.5 lb.)	1	41	25	5	5	8	9	0	33	0	8
	8	107	5	39	5	28	5	44	27	26	6
	14	153	73	61	0	27	3	29	4	49	5
	21	—	—	22	1	17	16	46	23	85	75
DDT (1.75 lb.)	1	109	70	31	31	14	30	33	38	0	8
	8	405	29	110	16	74	10	19	32	7	3
	14	300	272	132	24	44	26	21	4	68	9
	21	—	—	51	17	20	44	52	23	84	191
Experiment No. 2 (treatment applied July 10)											
Toxaphene (3.5 lb.)	15	78	24	—	—	26	22	3	10	5	0
	22	115	0	—	—	18	2	2	45	15	5
DDT (1.75 lb.)	15	195	129	—	—	81	68	1	16	5	6
	22	300	17	—	—	98	35	11	44	7	2
Pretreatment Count	9	2,381	489	—	—	218	62	6	10	14	41

[a] Replicated twice.
[b] A, adults; N, nymphs; L, larvae.

to the information obtained in the previously discussed experiments. However, since this was a seed alfalfa field in which *Orius* was feeding on thrips, it is possible that this reduction in abundance may reflect a differential kill of thrips by the two materials.

Kern County Experiment No. 2.—This experiment was similar in design and purpose to Kern County Experiment No. 1 (see Table 4). However, in this experiment pretreatment counts were taken. Unfortunately, the experiment had to be abandoned after the second posttreatment count because toxaphene drift during treatment of an adjoining cotton field was so heavy that it severely affected populations in all plots in the experimental field. The data obtained are valuable, however, for they reflect a considerable reduction of the several beneficial species (including *Orius*) by both materials but with a generally greater toxicity of toxaphene than of DDT.

In this experiment *Geocoris* populations were too low to provide useful data, but *Orius* counts appear to show significant reduction by toxaphene over DDT, as is also the case with *Nabis*. Counts of *Hippodamia* and *Chrysopa* showed no significant differences between treatments.

Discussion.—As previously stated, experimental data obtained from these studies are difficult to evaluate. Certain conclusions appear to be justified, however. All materials tested were toxic to the various beneficial insects to some degree and seemed to fall into three rather distinct groups insofar as severity of toxicity is concerned: (1) materials highly toxic to a number of beneficial species—parathion and the toxaphene-DDT combinations; (2) materials moderately toxic—toxaphene, DDT, and endrin (in this category DDT dust at the rate of 1 to 1.5 pounds per acre appeared to be the least toxic material); and (3) the material which was limited in its toxicity to a few beneficial species—demeton.

It was also shown in these experiments that there is a certain amount of specificity in the toxicities of the materials, particularly of toxaphene and endrin (group 2). Endrin appeared to be practically nontoxic to adults of *Hippodamia* on cotton, while DDT and toxaphene were rather severely toxic to this species. On the other hand, to *Geocoris*, DDT was distinctly less toxic than was toxaphene or endrin.

Another interesting phenomenon reflected by these experiments was the generally high degree of tolerance of *Chrysopa* larvae and of *Orius* sp. to the wide variety of materials.

So far as practical results are concerned, these studies indicate that where preservation of beneficial species is concerned the DDT-dust (in the range of 1 to 1.5 pounds active ingredient per acre) appears to be clearly the least harmful of the widely used materials. On the other hand, the DDT-toxaphene mixture, a treatment which is coming into increasingly greater usage, is severely toxic and should be used only where effect on predators is not a consideration.

Summary.—The beneficial insects in cotton and alfalfa fields in California play an important role in the natural control of pest insects. Any soundly devised pest control program on these crops should take advantage of natural control. To help attain this objective, an attempt was made to evaluate the effect of insecticides commonly used on these crops on the most important insect predators. The effects were studied on insects of the following genera: *Orius*, *Geocoris*, *Nabis*, *Chrysopa*, and *Hippodamia*.

Although difficult to evaluate the severity of toxicity, all materials tested were toxic to some degree and seemed to fall into three rather distinct groups: (1) Highly toxic—parathion and toxaphene-DDT combinations; (2) moderately toxic—toxaphene, endrin, and DDT (the latter material was the least toxic in this group); and (3) limited toxicity—demeton. Considerable specificity was evident in the toxicities of the various materials, particularly those in group 2.

Interestingly, *Chrysopa* larvae and *Orius* sp. were relatively tolerant to the wide variety of insecticides tested.

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Variation in Effectiveness of Derris Dusts against the Pea Aphid[1]

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One of the most important problems in the control of the pea aphid, *Macrosiphum pisi* (Harris), has been the great variation in the effectiveness of derris and other rotenone dusts. Differences occur from one year to another and in different fields during the same season. It seemed probable that the following factors might contribute to this variation: the thoroughness and time of application, the geographical source and species of the rotenone-bearing plants, the proportions of rotenone and related insecticides in the derris root, the fineness of milling of the roots and other differences in the manufacturing processes, the type and fineness of the diluents, the effects of temperature and humidity on the toxic action of the insecticide and on the growth and reproduction of the aphid, and the influence of rain and dew on the coverage and residues of the insecticides on the pea plants.

Effects of the chemical properties of rotenone-bearing plants and the problem of evaluating rotenone in combination with the other toxic substances in these plants have been discussed by Tattersfield & Martin (1935), Hoyer & Leonard (1936), and Jones & Smith (1936), and Martin (1940, 1942). Hutzel & Howard (1944) have studied the effects of physical properties of derris dusts and dusts coated with derris extractives on the Mexican bean beetle.

Investigations over a 5-year period in Maryland by Ditman and coworkers (1943) indicated that much of the variation in effectiveness of rotenone materials against the pea aphid was seasonal. The presence of moisture on the foliage at the time of application and the temperature before, during, and after treatment were of minor importance. However, derris sprays were most effective in years with the greatest rainfall either before or after the treatments. Derris was found to be significantly better than cube, and micronized cube better than ordinary ground cube root.

Wilson and coworkers (1941, 1944) found that the electrostatic charges of blown dusts produced with different diluents affect the deposit of particles on the plants and thus the degree of aphid control.

To obtain a better understanding of the reasons for such differences in effectiveness, the author conducted tests with derris dusts from various sources and under various controlled environmental conditions. This work was done at Twin Falls, Idaho, in 1940 and 1941 and at Columbus, Ohio, in 1943.

MATERIALS AND METHODS.—The aphids were grown on potted broad beans in the greenhouse. Those used in the tests were apterous females less than 24 hours after becoming adults.

The test plants were Perfection peas grown in sand in No. 2 tin cans with a complete nutrient solution according to the method described by Stone (1940). A disc of waxed paper was placed on the wet sand and fitted around the stems, and then covered with a layer of dry sand to minimize the effect of evaporation of the solution on the temperature and humidity within the cage.

Ten aphids were placed on each plant, and after they had become established were treated under a bell jar (Harries 1943) with 50 mg. of dust. The temperature and humidity under the bell jar were the same as those to which they were to be held during the observation period. After treatment the infested plants were covered with cylindrical cages about $5\frac{1}{4}$ inches high. These cages were made of galvanized screen to minimize their effect on temperature and humidity and were closed at the top with celluloid discs to admit as much light as possible. The caged plants were placed in cabinets equipped for maintaining constant temperatures and humidities. An undusted infested plant was included in each cabinet as a check. The plants were given light 12 hours each day from a 500-watt bulb and reflector mounted in the top of each cabinet over a shallow glass-bottom tray of running water to reduce heat as much as possible.

In each experiment the tests were made at random except that only one test of each treatment was started on any one day and all tests of a replicate were started on the same day. The plants were arranged at random in the controlled cabinets, there being only one cabinet for each temperature-humidity condition. Examinations were made daily at about 9 P.M., and for the tests at 85° and 80° F. also at about 9 A.M.

In some experiments moisture to simulate dew was applied by rotating each plant in a mist made by directing a fine jet of distilled water against a suitable baffle. This moisture was held on the plants by placing them in waxed-paper cartons lined with wet blotting paper and sealing the lids with decorators' tape. These cartons were

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also used to obtain saturation in atmospheric moisture.

The particle size of the dusts was determined as surface-mean diameter by the air-permeation apparatus described by Gooden & Smith (1940).

Only factorial experiments were conducted. Thus all the tests in any one experiment were utilized in studying each of two or more factors. For example, in experiment 1 there were 532 tests excluding checks, half at one temperature and half at another, half at one relative humidity and half at another, and one-seventh, or 76, were made with each of seven dusts. Thus comparisons of one type of treatment became hidden replicates for another.

The method of analysis was that used for split-plot designs in field experiments except in the last experiment, where there was no restriction in randomness by placing the plants under different temperatures and humidities. In experiment 1, for example, four cabinets constituted the whole plots with temperatures and humidities as the major treatments, and the individual plants were the split plots with seven dusts as the minor treatments.

All the dusts were prepared from ground derris root to contain 1 per cent of rotenone. The six samples of derris root in the dusts used in the first four experiments were selected on the basis of their total-extractives content, so that the dusts would also contain about the same proportion of the other extractives. Talc was used as the diluent. In experiment 1 an impregnated dust was included; it was prepared by spraying an extract of one of the samples onto talc. Dusts used in experiments 5 and 6 were prepared from special samples of derris and different diluents and with pyrophyllite of different degrees of fineness.

Effectiveness was based on the death of aphids or their inability to move the appendages, and in most of the experiments on the number of progeny. Appropriate control groups were included in all experiments.

EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY.—Treated aphids at 60° F. lived much longer than untreated aphids at 85°. Therefore, the treatments at the different temperatures could not be compared after equal time periods. The only way found to overcome this difficulty was to record the mortality each day until all the aphids in both the treated and untreated groups were dead and then calculate the percentage reduction in survival time.

The data on reduction in survival time, summarized in table 1, were not consistent. Experiments 1, 2, and 6 show a significant interaction of temperature with humidity, but the direction of the interaction in experiment 6 was the reverse of that in the other two experiments. In experiments 3 and 4 the reduction in survival time was greater at the higher humidity at both temperatures. A significant effect of temperature was shown only in experiment 5, where the reduction in survival time was greatest at the lower temperature.

It is suggested that the observed survival time was affected by the rate of desiccation of the aphids killed by rotenone. This would tend to minimize the estimate of the direct effect of the dusts at the higher humidities and lower temperatures. For this reason the number of surviving progeny would probably be a better criterion of the direct effects of temperature and humidity on the efficiency of the insecticide. In experiment 3 the smaller numbers of progeny at the higher temperature and higher humidity indicated that there was a greater insecticidal effect under these conditions. In experiments 4 and 6 there was also a greater insecticidal effect at the higher temperature, and in experiment 6 at the higher humidity. There is normally greater production of young at 60°–65° than at 75°–80°, as has been shown by Campbell (1926) and Schaefer (1933). Since the relative humidity usually

Table 1.— Effect of temperature and relative humidity on the toxicity to the pea aphid of derris dusts containing 1 per cent of rotenone.

Expt.	Aphids	Temperature	Relative Humidity	Reduction in Survival Time	Surviving Progeny per Plant
	Number	*° F.*	*Per Cent*	*Per Cent*	*Number*
1	1330	85	75	18	—
			25	34	—
		60	75	25	—
			25	18	—
L.S.D. (19:1)				9	—
2	480	80	80	25	—
			20	32	—
		62	80	32	—
			20	26	—
L.S.D. (19:1)				8	—
3	300	75	80	47	10
			20	45	18
		65	80	44	21
			20	39	39
L.S.D. (19:1)				[a]	11
4	240	72	80	48	9
			20	36	13
		60	80	43	28
			20	33	24
L.S.D. (19:1)				10	18
5	300	72	80	40	8
			20	42	15
		60	80	53	9
			20	54	13
L.S.D. (19:1)				7	[a]
6	400	75	80	34	73
			20	25	114
		65	80	29	141
			20	35	139
L.S.D. (19:1)				5	16

[a] Difference not significant according to the F test.

Table 2.—Effect of moisture on the toxicity of derris dust to the pea aphid in experiments 5 and 6.

Moisture Condition of Plants	Reduction in Survival Time	Surviving Progeny per Plant
	Per Cent	*Number*
Experiment 5, plants infested before dusting		
Kept dry	46	4.6
Wet when dusted	48	9.4
Wet after dusting	48	19.7
L.S.D. (19:1)	[a]	4.7
Experiment 6, plants infested after dusting and when dry		
Dry when dusted	41	67
Wet when dusted	20	167
L.S.D. (19:1)	2	13

[a] Difference not significant according to *F* test.

increases as the temperature goes down, the greater effectiveness of the dusts at higher humidities would tend to be counteracted by the greater production of young at lower temperatures. This makes it difficult to evaluate the effects, but the data indicate that temperature and humidity are not major sources of variation in control of the insect with rotenone dusts.

EFFECT OF MOISTURE ON THE PLANTS.—In experiment 5 one of the dusts was tested under different moisture conditions. Infested plants of one group were dusted when dry, a second group when wet, and a third group were dusted when dry and then moistened immediately afterward. The three treatments were compared under four environmental conditions at 72° and 60° F., with relative humidities of 80 and 20% at each temperature in each of 10 replicates.

The effects of these treatments are shown in table 2. Apparently, moisture had little effect on survival time, but increased the number of surviving progeny. This increase could only come from a decrease in effectiveness of the residues on the plants after drying. On the plants wet after dusting, the number of progeny was also significantly greater than on the plants that were wet when dusted. This may have been due to greater adherence of dust to the plants that were wet when dusted.

The effect of moisture on the plants was also tested in experiment 6. Half the 160 plants used in this experiment were dry and the remainder were wet when the dusts were applied. The aphids were not put on the plants until after the plants were dusted and the wet ones had been allowed to dry thoroughly. As is shown in table 2, the presence of moisture greatly reduced the effectiveness of the residues on both the adults and progeny.

In experiment 6 both dry and wet plants were dusted with mixtures of the same sample of derris with four diluents and held at 65° and 75° F. and 80 and 20% relative humidity at each temperature. Aphids were not placed on the plants until they had thoroughly dried.

Table 3 shows that moisture on the plants greatly reduced the residual effect of the dusts on both the adults and progeny. This reduction was significantly greater for the dusts containing the organic diluents walnut-shell flour and tobacco dust.

This loss in toxicity of the dust residues after drying may have been due to greater compacting of the residues, so that less toxic material was contacted or picked up by the aphids in moving about on the plants. When a few grams of each dust were wet and allowed to dry in petri dishes, those prepared from walnut-shell flour and tobacco dust seemed to form harder cakes than the others.

Table 3.—Effect of moisture on the residual toxicity of derris dusts containing different diluents on the pea aphid in experiment 6.

Diluent	Per Cent Reduction in Survival Time		Number Surviving Progeny per Plant	
	Plants Dry	Plants Wet	Plants Dry	Plants Wet
Pyrophyllite	50	36	28	95
Talc	45	26	53	130
Walnut-shell flour	39	14	76	213
Inert tobacco dust	30	5	110	230
L.S.D. (19:1)	5		18	

Table 4.—Effect of moisture conditions on the residual toxicity to the pea aphid of derris dust applied to dry plants.

Moisture Conditions	Per Cent Mortality on—		Per Cent Control	Number Surviving Progeny per Plant
	Undusted Plants	Dusted Plants		
				Number
Plants kept dry:				
Infested before dusting	9	72	69	4
Infested after dusting	9	62	58	8
Plants wetted, dried, then infested:				
Not further exposed to moisture	9	22	14	45
Kept dry 12 hours and wet 12 hours alternately	8	72	70	1
Kept dry 12 hours and in saturated air 12 hours alternately	6	56	53	1
Plants exposed to saturated air for 6 hours then infested	9	56	62	7
L.S.D. (19:1)	—	—	11	10

In experiment 7 further studies were made to determine whether the extreme loss of residual toxicity of the dust, apparently through caking, would be modified by the recurrence of free moisture or high humidity. Free moisture was held on some of the dusted plants, and others were held under humidity near saturation during alternate 12-hour periods in simulation of diurnal conditions where decreasing temperatures reach or approach the dew point. Plants receiving six different moisture treatments were dusted at 70° to 75° F. in four groups, and later held at 72° or 65° and a relative humidity of 20 or 80%. The tests were replicated eight times.

Table 4 shows the mortality of the adults on dusted and undusted plants receiving the same moisture treatments, and also the mean number of surviving progeny on the treated plants. There were highly significant effects of the free-moisture treatments and no significant interaction of these treatments with temperature and relative humidity treatments. When the plants were infested after they were dusted, the insecticidal effect was almost as great as when they were infested before the dusting. This illustrates the importance of the residual effect of the dust, which was largely lost when free moisture occurred on the plants and was allowed to dry. This loss in effectiveness due to wetting and drying of the residues was restored by the recurrence of moisture on the plants, and by the exposure to a humidity at or near saturation. Exposure of dusted plants to saturation in atmospheric moisture for 6 hours did not cause any significant loss in effectiveness.

These results indicate that derris or cube powder applied in sprays during dry weather would be caked in drying and tend to lose its residual toxicity. Dusts could therefore be expected to have a greater residual effect than sprays when applied during dry weather. Both sprays and dusts should be effective under recurring rain or dew, but there would be loss of residual toxicity when a period of free moisture during or shortly after the application is followed by one in which the foliage remains dry. The results also show that much of the loss in toxicity with the caking of the dust residues is counteracted by the occurrence of high humidity. Variation in the effec-

Table 5.—Relation between properties of derris samples and their effect on the pea aphid in experiment 1.

Derris Samples				Dusts Containing 1 Per Cent of Rotenone				
No.	Rotenone	Other Extractives	Average Particle Diameter	Derris Content	Total Extractives	Derris Particles per Gram	Reduction in Survival Time	Control
	Per Cent	*Per Cent*	*Microns*	*Per Cent*	*Per Cent*	*Number*	*Per Cent*	*Per Cent*
1[a]	—	—	—	—	3.0	—	29.4	50.4
2	5.2	10.3	4.8	19.2	3.0	174	25.3	42.7
3	3.3	6.5	5.6	30.3	3.0	172	24.5	43.9
4	9.0	14.0	4.8	11.1	2.6	100	23.8	42.4
5	4.8	9.9	8.0	20.8	3.1	41	23.8	40.5
6	2.2	4.4	8.4	45.5	3.0	77	21.5	33.9
7	8.3	13.1	6.4	12.0	2.6	56	19.8	32.0
L.S.D. (19:1)	—	—	—	—	—	—	3.4	7.0

[a] Impregnated dust.

tiveness of the dusts might therefore be reduced by the addition of hygroscopic agents. Some limited tests of lignin for this purpose were not very encouraging.

Effect of Properties of Powdered Derris.—Since in experiments 1 to 4 the interaction of dusts with temperature and humidity was not significant, the effects of physical and chemical properties of the dusts can be discussed independently of these factors.

The properties of the derris samples and the results of tests of the dusts containing them in experiment 1 are shown in table 5. The percentage of control was calculated with Abbott's formula from mortalities after 1½ days at 85° F. and 6 days at 60°, at which times the mortality of the untreated controls was approximately 17% at each temperature. The impregnated dust (No. 1), made from the extractives from sample No. 2, reduced the survival time significantly more than any others. It also gave better control than any other dust except No. 3. In the impregnated dust the toxic material probably was distributed over most of the particles, whereas only about 19% of dust No. 2 consisted of toxic particles. The other dusts, however, do not vary in toxicity according to the rotenone content of the derris, or, consequently, according to their derris content. For example, No. 2, which was prepared from derris containing 5.2 per cent of rotenone, was significantly more effective than Nos. 6 and 7, prepared from derris containing 2.2 and 8.3 per cent of rotenone. These results indicate that the toxicity also depends on the fineness of milling of the derris root.

The number of derris particles per gram of each dust was calculated from the particle size and the proportion of derris in the mixture. The number of derris particles was assumed to be inversely proportional to the cube of the particle diameter and directly proportional to the percentage of derris in the dust times 1,000. The calculation for dust No. 2 was $1/4.8 \times 19.2 \times 1{,}000 = 174$ (Table 5). The effectiveness of the dusts did not appear to be much more closely related to the number of derris particles than to the particle size.

Experiments 2, 3 and 4 showed significant correlations between effectiveness and particle size of the derris but not between effectiveness and the derris content of the dust. Effectiveness was not correlated any more closely with the number of derris particles than with the particle size.

To obtain more information on the effect of fineness of milling and the derris content of the dusts, four samples of different rotenone content were each ground to three different degrees of fineness and diluted to a strength of 1 per cent of rotenone with pyrophyllite of four degrees of fineness. The 48 dusts were tested in seven replicates in which the treated aphids were held for 3 days under fluorescent lights at 72° to 75° F. and 50% relative humidity. As shown in table 6, the effectiveness of the dusts was significantly reduced when the per cent of derris was greater than 16, when the particle size of the derris was greater than 7 microns, and when the particle size of the diluent was greater than 3 microns. The nonrotenone extractives varied from 1.3% to 3.6, being greatest in the least effective dust.

In experiment 6 some studies were made of the effects of different types of diluents. The dusts were mixed to contain 1 per cent of rotenone by combining portions of the same lot of derris with talc, pyrophyllite, walnut-shell flour, and inert tobacco dust. The four dusts were tested on both wet and dry plants under both high and low relative humidity at two temperatures. The effects of the

Table 6.—Effect of derris content and particle size on the toxicity of 1% rotenone dusts to the pea aphid.

Property	Per Cent Mortality of Adults	Number Surviving Progeny per Plant
Derris content (per cent)		
8.6	43	58
11.1	39	63
15.4	41	63
26.6	33	67
L.S.D. (19:1)	6	—
Particle size of derris (microns)		
6	41	60
7	41	63
9	35	65
L.S.D. (19:1)	5	—
Particle size of diluent (microns)		
3	53	45
6	34	79
9	40	70
12	35	68
L.S.D. (19:1)	5	7

Table 7.—Effect on the pea aphid of derris dusts containing different diluents.

DILUENT	AVERAGE PARTICLE DIAMETER	REDUCTION IN SURVIVAL TIME	SURVIVING PROGENY PER PLANT
	Microns	*Per Cent*	*Number*
Pyrophyllite	2.5	43	61
Talc	3.0	36	91
Walnut-shell flour	9.5	26	144
Inert tobacco dust	11.0	18	170
L.S.D. (19:1)	—	4	28

environmental conditions have already been discussed. The results of these tests, given in table 7, show that the diluent may have an important effect on toxicity of the dust. The data on both reduction in survival time and number of progeny show that the dust prepared from pyrophyllite was significantly more effective than that prepared from talc, which in turn was better than those prepared from walnut-shell flour and tobacco dust. The two dusts with mineral diluents were significantly more toxic than those with the organic diluents. But since dusts containing the coarser diluents were less toxic (Table 6) and the pyrophyllite and talc consisted of finer particles than the walnut-shell flour and the inert tobacco dust, no conclusions can be made.

SUMMARY.—Laboratory studies were made at Twin Falls, Idaho and Columbus, Ohio in 1940 to 1943 to determine the reasons for variation in the effectiveness of derris dusts against the pea aphid, *Macrosiphum pisi* (Harris). Dusts containing 1 per cent of rotenone from different samples of derris were tested in factorial experiments under different conditions of temperature, relative humidity, and free moisture on the plants.

Temperature and relative humidity had little effect on the reduction in the time of survival of the adult aphids, but there were fewer surviving progeny at the higher temperatures and humidities. Apparently these are not important factors in the effectiveness of the dusts.

More important effects were noted when the plants were wet with rain or dew. Moisture increased the residual action of the dusts while the plants were wet, but after drying most of the residual action was lost, apparently owing to caking or hardening. Thus, the dusts could be expected to be effective in both dry and wet weather, but poor control could result when the occurrence of moisture on the plants is followed by a period with no rain or dew.

Talc impregnated with derris extract was significantly more toxic than other derris-talc dusts with the same rotenone content. The toxicity of the dusts did not increase with the derris content, but did increase with greater fineness of grinding of the derris root, probably owing to more thorough breaking down of the plant structures. The kind of diluent and its particle size had a marked effect on the toxicity.

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Response of *Heliothis zea* (Boddie) and H. virescens (F.) to DDT and Endrin in Laboratory Toxicity Studies[1]

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The bollworm, *Heliothis zea* (Boddie), and the tobacco budworm, *H. virescens* (F.), are becoming increasingly important as pests of cotton in Louisiana. The damage they cause to cotton is exceeded only by that of the boll weevil. Recommendations for control of these pests have stressed the importance of properly timed applications in order to kill the newly hatched larvae. Such recommendations are based on field observations that young larvae are more easily controlled. However, very little information is available in the literature on comparative susceptibility to insecticides of the various instars of each species. Many examples of poor bollworm control have been observed where poorly timed applications are made. To better understand the reasons for unsatisfactory control of bollworms a study was made in the laboratory of the comparative susceptibility to insecticides of each instar of both species.

Review of Literature.—The bollworm is generally used as one of the standard test insects in screening programs for evaluation of possible cotton insecticides. Generally only third or later instar larvae are used for this purpose. Ivy *et al.* (1945) found that DDT was effective in laboratory and field cage tests for control of the bollworm. They considered that it acted primarily as a contact insecticide in controlling this pest. Parencia & Ewing (1948) using small plot field tests determined that 20% toxaphene, a mixture of 3% gamma isomer BHC plus 5% DDT and 40% sulfur, and 10% DDT gave equal control of the bollworm against light to moderately heavy infestations. Brazzel *et al.* (1953) reported results of comparative tests on *H. zea* and *H. virescens* with DDT and toxaphene as contact poisons, and with the above two insecticides and 3-5-40 as stomach poisons. All gave good control of both species although *H. zea* was more susceptible to DDT and 3-5-40 dust than was *H. virescens*. Toxaphene gave comparable results for the two species. No literature on comparative susceptibility of the different instars of *H. zea* and *H. virescens* is available, although field workers have recognized the importance of directing control measures at the early instars. A considerable amount of work has been reported on topical applications of DDT to house flies, cockroaches and grasshoppers. (Babers 1953, Kerr 1954.) However, no information is available on topical application of insecticides to *Heliothis* larvae.

Methods and Materials.—Larvae for test purposes were reared in the laboratory with wide-mouthed gallon glass jars used as oviposition cages. Adult *Heliothis* were placed in the jars and allowed to oviposit on the cloth cover or on strips of cloth attached to the cover. Cotton pads saturated with water-diluted honey were placed in the jars as food for the adults. In order to obtain larvae of a known age the adults were transferred to clean fresh jars at 24-hour intervals. The eggs were allowed to hatch in the oviposition jar. A fresh supply of food was added to each jar as hatching commenced. The newly hatched larvae readily collected on the food source. Fresh food was added as often as needed. Soybean seedlings, hairy vetch foliage, corn ears in the dough stage, or tender cotton terminals served as sources of larval food. When the larvae reached the third instar they were removed from the glass jar and placed under glass bowls 2 inches high and 6 inches in diameter. *H. virescens* larvae were kept in such bowls until they reached the fifth instar. Afterwards they were placed in lots of 10 in gallon jars with 3 inches of damp sand in the bottom. *H. zea* were placed individually in ½-pint jelly glasses when they reached the fifth instar. After pupation *H. zea* pupae were placed in gallon jars containing 3 inches of damp sand. A high percentage of normal adults of both species was obtained by this method.

For the purpose of comparing the response of the different instars of *H. zea* and *H. virescens*, tender cotton terminals were dusted in a conventional laboratory dusting tower. The insecticide dust was forced into the chamber from above by an air pressure pump. A 10% DDT dust was applied at the rates of 5, 10, and 15 pounds per acre in one series. A 3-5-40 (3% gamma isomer of BHC, 5% DDT and 40% sulfur) dust was applied at the rate of 5, 10, and 15 pounds per acre in another series. A cotton terminal was placed in the center of the tower and the proper amount of insecticide dusted into the chamber and allowed to settle for 5 minutes. The terminal was then removed from the tower and placed in a ½-pint jelly glass inverted on a folded paper towel. Three larvae were placed on a terminal, with the exception of sixth instar larvae, which were placed on individual terminals. Each replication within a series contained three larvae of each of the six instars. A small amount of water was applied to the towel daily in order to keep the terminals fresh during the experiment. The larvae were observed at 12-, 24- and 48-hour intervals and the number dead recorded. Abbott's (1925) formula was used to calculate the per cent killed.

For further comparisons of susceptibility of the two species, individual larvae were treated topically with a measured dosage of insecticide. The apparatus used for delivering the insecticides was similar to that described by Heal & Menusan (1948). Comparable groups of 20 larvae of each species were treated in each series. Larvae were weighed individually and isolated in ½-pint jelly glasses placed on numbered paper towels. Each larvae received 0.002 millileters of solution applied to the thorax. Clean food was supplied each larva. An acetone treated control group was included in each series to ascertain the effect of the solvent on the test insects. Insecticide solutions of DDT and endrin were prepared from technical chemicals dissolved in acetone. The treated larvae were inspected at intervals of 12-, 24-, and 48-hours after application and records were taken of the

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Table 1.—The effect of 10% DDT dust on *Heliothis zea* larvae applied at the rates of 5, 10, and 15 pounds per acre.

	Per Cent Control								
	Rate of Insecticide Application								
	5 Pounds			10 Pounds			15 Pounds		
	Hours			Hours			Hours		
Instar	12	24	48	12	24	48	12	24	48
1st	100	100	100	100	100	100	100	100	100
2nd	81	100	100	95	100	100	95	100	100
3rd	5	19	76	24	62	95	38	95	100
4th	0	5	24	10	29	67	24	57	81
5th	0	0	5	0	0	0	10	10	19
6th	0	0	0	0	0	5	0	5	14

larva's condition at each check. The dosage each larva received was computed in milligrams per gram body weight.

One test, in which *H. virescens* was used to compare the effect of host on the susceptibility of the species, was analyzed by the methods of Bliss (1938). The other tests where topical applications were made were analyzed by means of Student's T test and by the Chi-square method.

Results.—Ten per cent DDT applied to terminal growth of cotton at the rate of 5, 10, and 15 pounds per acre readily controlled the first and second instar of both species within 24 hours. At the rate of 5 pounds of 10 per cent DDT per acre very few larvae of either species past the third instar were killed within 48 hours. Results are summarized in tables 1 and 2.

Fair kill of fourth instar larvae of *H. zea* and *H. virescens* was obtained with 10 and 15 pounds of 10% DDT in 48 hours. Very few larvae of either species in the fifth and sixth instars were killed with the 10% dust.

Where 3–5–40 dusts were applied at the rate of 5, 10, and 15 pounds per acre to cotton terminals subsequently infested with *H. zea* 100% control of first instar larvae was obtained with 5 pounds per acre rate in 12 hours. Eighty-three per cent of the third instar larvae were controlled at this rate in 48 hours; at the 10- and 15-pound rates, 100 per cent of the third instar larvae were controlled in 48 hours and 80 and 100%, respectively of the fourth instar larvae. Very few of the fifth and sixth instar larvae were killed in the test. Results are summarized in table 3.

Table 2.—The effect of 10% DDT dust on *Heliothis virescens* larvae applied at the rate of 5, 10, and 15 pounds per acre.

	Per Cent Control								
	Rate of Insecticide Application								
	5 Pounds			10 Pounds			15 Pounds		
	Hours			Hours			Hours		
Instar	12	24	48	12	24	48	12	24	48
1st	87	100	100	100	100	100	100	100	100
2nd	40	80	100	73	100	100	87	100	100
3rd	0	7	60	13	40	100	26	67	100
4th	0	0	27	0	20	80	0	40	93
5th	0	0	0	0	0	0	0	0	13
6th	0	0	0	0	0	0	0	0	0

Table 3.—The effect of 3-5-40 dust on *Heliothis zea* larvae applied at the rate of 5, 10, and 15 pounds per acre

	Per Cent Control								
	Rate of Insecticide Application								
	5 Pounds			10 Pounds			15 Pounds		
	Hours			Hours			Hours		
Instar	12	24	48	12	24	48	12	24	48
1st	100	100	100	100	100	100	100	100	100
2nd	83	100	100	92	100	100	100	100	100
3rd	8	41	83	42	80	100	42	92	100
4th	0	0	29	8	25	80	8	38	100
5th	0	0	0	0	0	0	0	8	8
6th	0	8	8	0	0	0	0	0	0

Results from topical applications of DDT and endrin to *H. zea* and *H. virescens* are given in tables 4 and 5. Larval stages of *H. zea* were significantly more susceptible to both insecticides than were larval stages of *H. virescens*.

Table 6 gives results of tests with *H. virescens* reared on soybean seedlings and hairy vetch foliage. The LD-50 for larvae reared on soybean seedlings was 0.073 milligram per gram of body weight compared to an LD-50 of 0.083 milligrams per gram body weight for larvae reared on hairy vetch. The difference between dosages was not significant.

Discussion.—Results of the study showed that a greater percentage of young *H. zea* larvae was controlled in 12 hours than larvae of *H. virescens*. The control of the first four instars of both species was equal after 48 hours exposure to DDT. Fifth and sixth instar larvae of both species were able to survive 48 hours exposure to 15 pounds of 10% DDT dust. As the larvae increased in age and size the per cent control decreased so that only fair control of fourth instar larvae was obtained, with no significant control of fifth and sixth instar larvae. Figure 1 depicts graphically the control of *H. zea* obtained in laboratory tests when cotton terminals were treated with

Table 4.—The effectiveness of DDT dissolved in acetone when applied topically to the thorax of *Heliothis zea* and *H. virescens* larvae reared on corn.

	Weight of Larvae in Mg.	Dosage in Mg./Gm. of Body Weight	Total No. Larvae	Number Dead	Per Cent Dead
		H. zea			
Low	64	0.045	96	63	67.7
High	132	.093			
Range	67	.047			
Average	85	.072			
		H. virescens			
Low	55	0.057	96	27	28.1
High	105	.108			
Range	50	.052			
Average	82	.077			

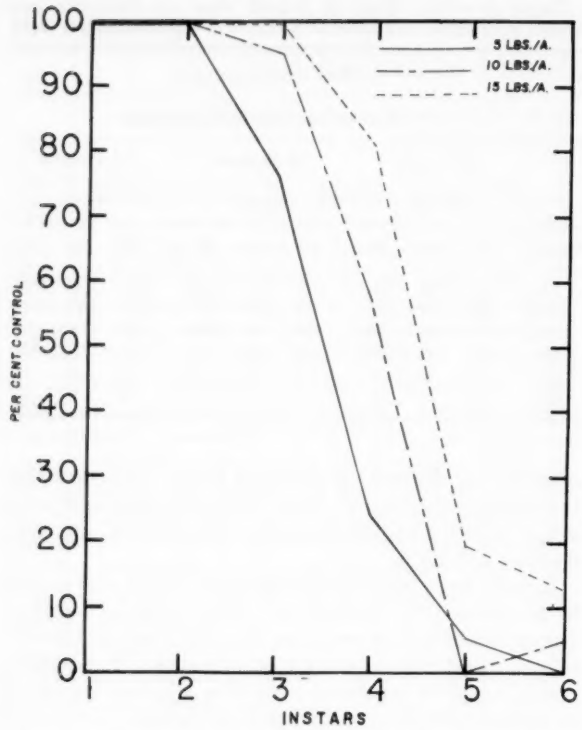

FIG. 1. Control of *H. zea* larvae with 10% DDT dust at rates shown after 48 hours exposure.

10% DDT dust and infested with the different instar larvae. The sharp reduction in control of the fourth, fifth and sixth instar larvae in laboratory tests emphasizes the necessity of properly timed thorough application of this insecticide for adequate control of bollworms in cotton.

The insecticide dust mixture 3-5-40 gave results quite similar to that obtained with the 10% DDT dust. Although it has been generally accepted that gamma isomer of BHC is relatively ineffective for control of bollworm—in fact application of this insecticide in cotton fields without DDT added is usually followed by increased bollworm populations—these data clearly show that 5% DDT in this dust mixture is equal to 10% DDT

Table 5.—The effectiveness of endrin dissolved in acetone when applied topically to the thorax of *Heliothis zea* and *H. virescens* larvae reared on corn.

	Weight of Larvae in Mg.	Dosage in Mg./Gm. of Body Weight	Total No. Larvae	Number Dead	Per Cent Dead
		H. zea			
Low	58	0.0060	112	70	62.5
High	103	.0127			
Range	45	.0067			
Average	75	.0083			
		H. virescens			
Low	55	0.0065	144	42	36.8
High	95	.0122			
Range	40	.0057			
Average	75	.0083			

Table 6.—The effectiveness of DDT dissolved in acetone when applied topically to the thorax of *Heliothis virescens* larvae reared on soybean seedlings and hairy vetch.

	Weight of Larvae in Mg.	Dosage in Mg./Gm. of Body Weight	Total No. Larvae	Number Dead
		Soybean seedling		
Low	52	0.063	96	64
High	95	.116		
Range	43	.053		
L.D. 50		.073 ± .0099		
		Hairy vetch		
Low	72	0.065	96	46
High	93	.126		
Range	20	.061		
L.D. 50		.083 ± .0149		

dust when applied alone for bollworm control. Whether BHC is an additive compound in this mixture or whether it increases the speed of entrance of DDT is not known. Armstrong *et al.* (1951, 1952) demonstrated that BHC penetrated the insect cuticle more rapidly than does DDT.

Topical application of DDT and endrin on the thoracic segments of the larvae showed that *H. zea* was more susceptible to both insecticides than *H. virescens*. The results of this method of application of insecticide are similar to that obtained by Brazzel *et al* (1953) who reported a substantial difference in the LD-50 of DDT for *H. zea* and *H. virescens* based on the amount of poison consumed per gram of body weight. This difference in susceptibility between the two species is sufficiently great to justify consideration of the species involved in a field infestation. It may also help explain many reported failures of insecticide applications to control bollworm outbreaks.

Larvae of *H. virescens* reared on soybean seedlings or hairy vetch foliage responded alike to topical applications of DDT.

SUMMARY.—Laboratory toxicity studies of the six larval instars of *Heliothis zea* (Boddie) and *H. virescens* (F.) with 10% DDT dust showed that the first three instars of both species were readily controlled. In the fourth instar many larvae survived the treatment. Very few fifth and sixth instar larvae of either species were killed with dosages as high as 15 pounds of 10% DDT dust per acre. A BHC-DDT-sulfur mixture (3-5-40) gave control similar to that obtained with the 10% DDT dust.

Topical application of DDT and endrin showed that *H. zea* was more susceptible to both insecticides than larvae of *H. virescens*. *H. virescens* exhibited no difference in susceptibility to DDT when reared either on soybean seedlings or hairy vetch foliage.

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Insects Attacking Red Clover in Rhode Island and Their Control[1,2]

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Red clover is commonly a two-year crop in Rhode Island. It can be harvested during the year of seeding and the following year. By spring of the third year, little or nothing remains of the stand. The failure of the crop after such a short time poses questions on why this should be true. An initial survey of the problem showed that several factors could be responsible, particularly those connected with insects and/or diseases. Accordingly, research on some of the entomological aspects of the problem was conducted during the period of 1951 to 1954, inclusive. Particular emphasis was given to: (1) ascertaining the insects of importance in red clover production; (2) the relative influence of the various insect species on both the crop yield and the maintenance of stand; and, (3) the relative effectiveness of various insecticides in promoting increased clover yields.

MATERIALS AND METHODS.—In 1951, plots of year-old medium red clover 61 feet wide and 85 feet long were utilized. During the period of 1952 to 1954, inclusive, plots of Kenland red clover 20 feet wide and 20 feet long that had been planted in early April, 1952 were used.

Periodically, the insects in each plot were collected by sweeping with a 12-inch net. Except as indicated otherwise, 25 sweeps were made in each of four randomized plots that constituted a treatment. In 1951 and 1952, collections were made both diurnally and nocturnally. In 1953 and 1954, all collections were diurnal.

In 1951, dust mixtures containing 1.5% lindane, 5% DDT, or 5% chlordane were applied with power-operated equipment to the first and third crops of clover at rates of 42, 63, and 65 pounds, and 44, 73, and 50 pounds per acre, respectively, for the three insecticides in the order listed. In 1952, a 5% DDT dust was applied to two crops of clover using hand-operated equipment at rates fluctuating from 30.2 to 39.2 pounds per acre. As indicated in the tables, some plots were dusted three times, while others received 4 or 7 applications. Wettable 50% DDT was applied to the second and third crops in 1953, while wettable 25% malathion was applied to the first crop in 1954. The sprays were applied with power-operated equipment at the rate of 200 gallons per acre.

Three crops of clover were harvested in 1951 and 1953; two were harvested in 1952 and 1954. Green and dry weight yield data were obtained from representative field samples on all dates of harvest.

Records were obtained on 37 species of insects, most of them of economic importance. For the purpose of brevity, some related species have been grouped together. The term "grasshoppers" refers to all species of *Acrididae* collected, most of which were *Melanoplus femur-rubrum* (DeG.) and *Chortophaga viridifasciata-virifasciata* (DeG.). The term "aphids" refers to all species collected, the most abundant of which was the pea aphid, *Macrosiphum pisi* (Harr.). In the tables, data are included under respective box heads for the six-spotted leafhopper, *Macrosteles fascifrons* (Stal.), the clover leafhopper, *Aceratagallia sanguinolenta* (Prov.), *Agallia constricta* (Van D.) and *Graminella nigrifrons* (Forbes). "Other leafhoppers" refers to undetermined specimens of immature leafhoppers and to the adult stage of *Paraphlepsius irroratus* (Day), *Cloanthus frontalis* (Van D.), *Draeculacephala antica* (Walk.), *Empoasca fabae* (Harr.), *Deltocephalus flavicosta* (Stal.) and *Endria inimica* (Say); all, except the latter two, were species collected in relatively small numbers.

Additional insects were *Sitona hispidula* (F.), *S. flavescens* Marsh, *Hypera meles* (F.), *H. nigrirostris* (F.), *H. punctata* (F.), *Tychius stephensi* (F.), *Colaspis flavida* (Say), *Popillia japonica* Newm., *Lygus lineolaris* (P.de B.) and *Philaenus leucophthalmus* (L.) Since few specimens of Lepidoptera were obtained, no data concerning this order are presented. The clover root borer, *Hylastinus obscurus* (Marsh) was not found during the course of the investigations.

1951 EXPERIMENTS.—Data on the seasonal collections of the most abundant insect species are included in table 1. Information on the respective diurnal and nocturnal collections of the less abundant species in all treatments was as follows: *Hypera meles*, 26 and 27; *H. nigrirostris*, 39 and 93; *H. punctata*, 1 and 21; *Tychius* stephensi, 34

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[2] The data on insecticide residues were supplied by R. M. Beverage and C. L. Olney, assistant chemists, Department of Agricultural Chemistry.

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Table 1.—Effect of various insecticides applied April 24 and July 16 on the numbers of insects collected diurnally and nocturnally in medium red clover. Kingston, R. I., 1951.

Collection Dates	Crop	Treatment	*S. hispidula*	*S. flavescens*	Grasshoppers	*P. japonica*	*L. lineolaris*	Aphids	*A. sanguinolenta*	*M. fascifrons*	*G. nigrifrons*	*A. constricta*	Other Leafhoppers
							Diurnal Collections						
May 1, 29	First	Check	3	2	2	0	15	1,509	0	0	0	16	3
		DDT	2	0	3	0	9	1,010	0	0	0	5	4
		Lindane	5	1	0	0	9	500	1	2	0	9	0
		Chlordane	0	1	1	0	8	1,426	1	0	0	12	1
July 11	Second	Check	32	36	6	2	59	447	3	4	0	0	7
		DDT	48	42	10	2	60	252	1	2	1	0	4
		Lindane	30	64	8	0	54	231	2	6	0	0	6
		Chlordane	36	57	14	1	51	297	19	19	0	2	11
July 27, Aug. 6, 13, 23	Third	Check	2	38	15	118	87	112	11	78	6	53	17
		DDT	1	17	13	117	78	257	3	68	11	12	2
		Lindane	3	46	6	94	62	10	10	48	5	29	7
		Chlordane	7	29	2	84	50	195	18	210	8	82	16
Sept. 5, 19, Oct. 15	Rowen	Check	4	6	15	4	124	185	100	195	126	14	162
		DDT	2	0	19	1	49	174	18	150	85	4	83
		Lindane	3	2	20	3	80	221	120	196	120	6	125
		Chlordane	2	2	14	1	54	60	236	601	214	12	265
							Nocturnal Collections						
April 25, May 8	First	Check	8	8	0	0	27	32	0	0	0	2	1
		DDT	0	0	0	0	6	8	1	0	0	1	0
		Lindane	1	0	1	0	1	4	2	0	0	1	1
		Chlordane	4	3	1	0	2	5	3	0	0	0	0
July 6	Second	Check	104	18	25	2	65	504	6	14	0	9	16
		DDT	91	23	9	2	43	204	1	2	1	0	7
		Lindane	77	16	6	7	30	164	3	1	0	0	7
		Chlordane	61	15	18	1	41	260	1	1	1	0	6
July 30, Aug. 13, 23	Third	Check	14	37	10	53	27	21	2	7	3	6	4
		DDT	2	18	32	24	47	34	0	10	0	7	0
		Lindane	18	92	8	56	40	6	10	18	1	41	3
		Chlordane	4	32	5	34	32	11	16	52	4	63	4
Sept. 5	Rowen	Check	0	0	3	1	11	0	1	4	0	0	1
		DDT	0	0	4	0	5	0	1	1	0	0	0
		Lindane	0	0	4	1	5	0	2	5	1	0	4
		Chlordane	1	1	3	1	4	0	3	4	3	3	6

and 18; *Philaenus leucophthalmus*, 31 and 11; *Empoasca fabae*, 96 and 27; and *Colaspis flavida*, 15 and 128.

Except aphids, which were controlled by lindane, there were few insects on the first crop of clover. Also, table 2 shows there were no significant yield differences between treatments when the first crop of clover was harvested.

Although the second crop of clover was not dusted, the aphid population in the insecticide treatments was approximately half that of the check treatment on the two insect collection dates. There were no great differences between treatments as far as the other insects were concerned. The second crop of clover showed a significant increase in yield, on a green weight basis, of the lindane treatment over that of both the check and chlordane treatments. It is believed that this resulted from the control of the aphid population earlier. The yield, on a dry weight basis, showed no significant differences between treatments.

In the third crop of clover, the green weight yield of the DDT treatment was greater than the check treatment, while the yield of both the DDT and lindane treatments was greater than that of the chlordane treatment. Also, the dry weight yield of both the DDT and lindane treatments was greater than either the check or chlordane treatments.

Seasonally, DDT was the most effective insecticide against all species of leafhoppers, except *Macrosteles fascifrons*. The total seasonal population of all leafhopper species in the DDT treatment was approximately half that of the untreated check, while in the lindane treatment it was almost equal to, and in the chlordane treatment it was 2½ times greater than the check. None of the

Table 2.—Effect of various insecticides on the yield of medium red clover. Kingston, R. I., 1951.

Insecticide	No. of Applications			Yield per Acre (Tons)							
				Green Weight				Dry Weight			
	Crop			Crop				Crop			
	1	2	3	1	2	3	Total	1	2	3	Total
DDT, 5%	1	0	1	11.6	4.5	3.1	19.2	1.61	0.87	0.66	3.14
Lindane, 1¼%	1	0	1	11.4	5.1	2.9	19.4	1.58	.88	.63	3.09
Chlordane, 5%	1	0	1	10.7	3.9	2.3	16.9	1.47	.73	.50	2.70
None				10.5	4.0	2.4	16.9	1.45	.72	.52	2.69
L.S.D. at 5% level				2.8	1.0	.6	3.6	.40	.23	.11	.60

insecticides were effective in reducing populations of the tarnished plant bug, the Japanese beetle, the grape colaspis, the two species of *Sitona*, and grasshoppers.

Sitona hispidula was collected more readily at night than during the day. Approximately equal ratios existed in the day and night collections of aphids, of *S. flavescens* and of grasshopper species. Among other species of insects greater numbers of the tarnished plant bug, the Japanese beetle and the various species of leafhoppers were collected during the day than at night.

On October 19, 1951, an examination of the stand showed 5.4, 3.8, 4.0 and 5.5 live clover plants per square foot for the lindane, chlordane, DDT and check treatments, respectively. By April 4, 1952, these numbers had been reduced to 3.0, 1.1, 2.2 and 2.3 live plants per square foot. Many of these succumbed before the end of April, at which time the experiment was discontinued. Examination of many of the plants from the various treatments showed that death of the clover could be attributed to root rot. The pathogens associated with the root rot were *Fusarium* spp.

1952 EXPERIMENTS.—In addition to the insects already listed, two other species, the potato flea beetle, *Epitrix cucumeris* (Harr.) and a mirid, *Melanotrichus flavosparsus* (Sahl.) were found in abundance. Since few specimens of either species were collected on the second crop, it is assumed that these two insects were attracted by the weeds, most of which were decimated when the first crop of clover was harvested. Also, few specimens of the three species of *Hypera* and of *Tychius stephensi* were collected during the season.

The data presented in table 3 refer to the insects collected from plots receiving no dust and from those receiving four applications of dusts on the first crop and a total of seven applications on both the first and second crops. The tarnished plant bug, grasshoppers and several species of leafhoppers were the most abundant insect species on the first crop of clover. The four applications of DDT were effective in reducing the population of all except grasshoppers. Both the green and dry weight yield of the DDT treatment, the data of which are presented in table 4, showed a significant increase over that of the untreated check.

While approximately equal numbers of the tarnished plant bug were collected in the DDT and check treatments of the second crop of clover, there were fewer specimens of this insect on the second crop than on the first. Slightly larger numbers of grasshoppers were found in the DDT treatment than in the check. Also, the aphid population of the DDT treatment greatly exceeded that of the check. Both green weight and dry weight yield data showed no significant differences between treatments when the second crop was harvested.

Seasonally, there were relatively few specimens of *Sitona hispidula*, *S. flavescens*, *Colaspis flavida* and *Philaenus leucophthalmus* collected. Even so, DDT was effective in reducing the populations of all of them. DDT was slightly effective against the immature stages of grasshoppers previous to harvesting the first clover crop but ineffective against adults later in the season. The use of DDT resulted in a reduction of 35 per cent in the population of the Japanese beetle, but produced a tenfold increase in the aphid population. Among the leafhopper species, DDT was slightly more effective against

Table 3.—Effect of DDT and malathion on the numbers of insects collected in Kenland red clover. Kingston, R. I., 1952–54.

Crop[a]	Collection Dates	Treatment	Pounds in 100 Gal. of Water[b]	Grasshoppers	*P. japonica*	*L. lineolaris*	Aphids	*A. sanguinolenta*	*M. fascifrons*	*G. nigrifrons*	*A. constricta*	Other Leafhoppers
						1952						
First	July 1, 3, 7, 16	Check		263	16	1,229	78	35	480	18	44	120
		DDT, 5%		114	34	293	23	1	78	3	1	15
Second	Aug. 8, 13, 26,	Check		201	239	34	169	98	64	50	136	86
	Sept. 3, 11	DDT, 5%		238	133	32	2,676	10	36	17	71	53
						1953						
First	May 6, 19, 25	None		37	0	18	6,672	11	2	0	251	0
Second	June 24, 30,	Check		460	34	120	1,622	0	5	1	6	6
	July 7	DDT, 50W	2	303	61	81	393	1	13	1	0	11
		DDT, 50W	1(7)	566	54	96	1,043	4	6	0	0	6
		DDT, 50W	1(3)	374	54	92	1,068	0	6	0	0	6
Third	Aug. 11, 19	Check		68	144	11	41	2	0	2	6	0
		DDT, 50W	2	119	247	4	374	0	4	5	9	0
		DDT, 50W	1(7)	57	214	10	522	0	2	2	18	0
		DDT, 50W	1(3)	55	322	16	490	0	6	0	6	0
Rowen	Sept. 1, 18, 25,	Check		80	8	31	481	14	66	76	0	28
	Oct. 9	DDT, 50W	2	110	2	26	662	4	87	98	0	42
		DDT, 50W	1(7)	100	4	20	1,681	2	49	102	0	39
		DDT, 50W	1(3)	104	6	37	1,044	10	82	79	0	48
						1954						
First	May 6, 18, 27,	Check		16	0	24	3,772	4	29	5	35	12
	June 1, 9	Malathion, 50W		21	0	17	1,608	0	20	6	64	5

[a] In 1952, dusts were applied to the first crop on June 25, July 1, 7, and 16; to the second crop on Aug. 8, 13 and 26.
In 1953, sprays were applied to the first crop on June 18 to the second crop on August 7.
In 1954, one spray was applied on May 4.

[b] Figures in parenthesis refer to number of DDT dusts applied the previous season.

Table 4.—The effect of DDT and malathion on the yield of Kenland red clover, Kingston, R. I. 1952–54.

Treatment			Applications per Acre							Yield per Acre (Tons)							
										Green Weight				Dry Weight			
			1952		1953			1954		Crop				Crop			
1952	1953[a]	1954[a]	1	2	1	2	3	1	2	1	2	3	Total	1	2	3	Total
													1952				
5% DDT			4	3						2.3	3.0	—	5.3	0.53	0.60	—	1.13
5% DDT			4	0						1.9	2.4	—	4.3	0.45	0.48	—	0.93
5% DDT			0	3						1.6	2.9	—	4.5	0.41	0.59	—	1.00
None										1.1	2.5	—	3.6	0.30	0.53	—	0.83
			L.S.D. at 5% level							0.6	0.7	—	1.2	0.13	0.13	—	0.22
													1953				
5% DDT	None		4	3	0	0	0			9.9	4.7	2.2	16.8	1.46	1.06	0.45	2.97
5% DDT	None		4	0	0	0	0			13.6	4.6	1.7	19.9	1.86	1.02	0.34	3.22
5% DDT	None		0	3	0	0	0			10.6	4.4	2.3	17.3	1.60	1.06	0.48	3.14
5% DDT	DDT 50W @ 1		4	3	0	1	1			11.9	5.0	1.9	18.8	1.80	1.13	0.44	3.37
5% DDT	DDT 50W @ 1		0	3	0	1	1			12.2	6.1	2.5	20.8	1.74	1.30	0.55	3.59
None	DDT 50W @ 1		0	0	0	1	1			10.8	3.6	2.0	16.4	1.62	0.82	0.40	2.84
None										11.0	3.0	1.3	15.3	1.70	0.69	0.28	2.67
			L.S.D. at 5% level							1.8	1.0	0.7	2.5	0.31	0.18	0.16	0.50
													1954				
5% DDT	None	None	4	3	0	0	0	0	0	1.8	0.69	—	2.49	0.35	0.16	—	0.51
5% DDT	None	None	4	0	0	0	0	0	0	2.4	0.86	—	3.26	0.49	0.21	—	0.70
5% DDT	None	None	0	3	0	0	0	0	0	2.3	1.00	—	3.30	0.45	0.24	—	0.69
5% DDT	DDT 50W @ 1	None	4	3	0	1	1	0	0	3.0	0.88	—	3.88	0.59	0.21	—	0.80
5% DDT	DDT 50W @ 1	None	0	3	0	1	1	0	0	3.3	0.93	—	4.23	0.67	0.24	—	0.91
None	DDT 50W @ 2	None	0	0	0	1	1	0	0	4.5	1.22	—	5.72	0.94	0.30	—	1.24
None	None	Malathion 25W @ 4	0	0	0	0	0	1	0	3.6	1.01	—	4.61	0.76	0.25	—	1.01
None	None	None								2.5	0.74	—	3.24	0.55	0.18	—	0.73
			L.S.D. at 5% level							1.0	—	—	1.22	0.21	—	—	0.26

[a] Pounds in 100 gallons of water.

the clover leafhopper and the potato leafhopper than the other species listed. The treatment receiving seven applications of DDT dust was the only one to produce significantly greater green weight and dry weight yields than the check treatment.

While both crops of clover were analyzed for DDT residue at harvest time, data are available only for the second crop. Clover on which the last three DDT dusts were applied yielded 15 p.p.m. of the insecticide on a dry weight basis, while untreated clover showed none.

1953 EXPERIMENTS.—Few specimens of the potato flea beetle and *Melanotrichus flavosparsus* that had been collected in abundance in early 1952, were found. Also, few *Hypera nigrirostris*, *H. punctata*, *Tychius stephensi*, *Colaspis flavida*, *Sitona hispidula*, *S. flavescens*, *Philaenus leucophthalmus* and *Empoasca fabae* were collected. *Hypera meles* was relatively abundant during May, a total of 67 specimens being found, but only 4 were obtained during the remainder of the season.

Aphids and one species of leafhopper, *Agallia constricta*, were the most abundant of the insects present on the first crop of clover. Although no insecticide had been applied to this crop thus far in the current season, the treatment receiving four dusts on the first crop in the previous year showed a significant difference in green weight yield as compared to the untreated check. It is suggested that this difference was attributable to the treatment applied in 1952. One enigmatic difference is that which existed between the two treatments that had been dusted with DDT seven times during 1952. This difference could be attributable to the depredation by woodchucks, *Marmota monex*, that seriously damaged some replicates of this treatment.

For a short period of time the first spray, particularly at the 2-pound level, resulted in a slight reduction of the populations of aphids, the tarnished plant bug and grasshopper nymphs on the second crop of clover. Contrariwise, larger numbers of the Japanese beetle were collected in the DDT treatments than in the untreated check. With the exception of the greater concentration of DDT, all treatments produced greater green and dry weight yields than the untreated check.

Because a broken net resulted in a lost sample while sweeping the untreated check on August 19, it is difficult to present a complete analysis of the effectiveness of the second spray. However, it appears that the sprays were only slightly effective in reducing the populations of grasshoppers and the Japanese beetle. When harvested, certain of the treatments showed significant increases in both dry weight and green weight yields over that of the untreated check, as indicated in table 4.

The total seasonal green weight and dry weight data show three treatments that had significantly greater yields than the check. They were: (1) 4 DDT dusts in 1952 and no DDT sprays in 1953; (2) 3 DDT dusts in 1952 and 2 DDT sprays in 1953; and, (3) 7 DDT dusts in 1952 and 2 DDT sprays in 1953.

From September 9 to October 9 there was a gradual increase in the aphid population, particularly in the DDT treatments. The total leafhopper population reached a peak on September 18 and diminished gradually thereafter. The grasshopper and tarnished plant bug populations remained at relatively low levels throughout the period.

The first crop of clover was analyzed for DDT residue by sampling the forage 5 and 19 days after the insecticide was applied, the latter time being the harvest date. On a dry weight basis, DDT applied at the rate of 2 pounds of actual insecticide per acre showed 261 p.p.m. and 17 p.p.m., respectively, for the days indicated, while the 1-pound rate showed 75 p.p.m. and 6 p.p.m.

1954 EXPERIMENTS.—Few specimens of the potato

flea beetle, the mirid, *Melantotrichus flavosparsus*, the curculionid species *Hypera meles*, *H. nigrirostris*, *H. punctata*, *Sitona hispidula*, *S. flavescens* and *Tychius stephensi* as well as *Colaspis flavida*, *Philaenus leucophthalmus* and *Graminella nigrifrons* were collected.

As in 1953, the most abundant insects on the first crop of clover were aphids and the leafhopper, *Agallia constricta*. The single malathion spray effectively reduced the aphid population. Although the numbers of *A. constricta* were relatively small in comparison, there were approximately twice as many specimens of this leafhopper collected in the malathion treatment as in the check. The clover on which the greater concentration of DDT had been applied during the 1953 season, and that which received malathion during the current season, produced significantly greater green weight and dry weight yields than the untreated clover. Also, the former treatment outyielded all other treatments, except the latter. Difficulty with woodchucks was experienced again in 1954, the result being low clover yields from plots that had received seven applications of DDT dust in 1952.

The numbers of all species of insects, except aphids and some leafhoppers increased on the second crop of clover. Between treatments there were no differences in yield at time of harvest. Seasonally, the green and dry weight yields of the treatment receiving the spray of wettable 50 per cent DDT at the 2-pound level in 1953 and the malathion treatment of the 1954 season were greater than the check. In addition, the former treatment yielded a significantly greater amount of clover than all other treatments, except the latter.

During April and early May, many of the clover plants in the experimental area, irrespective of insecticide treatment, succumbed to disease. A *Fusarium* root rot similar to that encountered in the 1952 experiment was identified as the apparent cause. In late May, another disease identified as northern anthracnose, incited by *Kabatiella caulivora* (Kirch.) Karak, resulted in the loss of much clover foliage throughout the experimental area.

Clover foliage sprayed with malathion on May 4 was analyzed for the presence of the insecticide on May 12, at which time residues amounting to 7.7 p.p.m., green weight basis, and 44.2 p.p.m., dry weight basis, were found. At the time of harvest on June 9, the residue had been reduced to less than 0.25 p.p.m. and less than 1.2 p.p.m. respectively, on the basis listed above.

SUMMARY.—The insects of importance in the production of red clover, the control of such insects through the use of various insecticides and the resulting clover yields were investigated in Rhode Island during the period of 1951 to 1954, inclusive.

Data are presented on the occurrence of the aerial forms of 24 of 37 insect species recorded, the most abundant of which were *Macrosiphum pisi* (Harr.), *Lygus lineolaris* (P. de B.), *Melanoplus femur-rubrum* (Deg.), *Popillia japonica* (Newm.), *Macrosteles fascifrons* (Stal.) and *Agallia constricta* (Van D.).

Lindane and malathion were effective for control of aphids, and DDT reduced populations of various species of weevils, beetles and leafhoppers. The use of chlordane resulted in leafhopper populations 2½ times those on untreated clover.

The use of dusts and sprays of lindane, DDT and malathion resulted in increased yields of clover. On several occasions, the increased yields were not obtained from the crop to which the insecticide had been applied, but were experienced in succeeding crops of the same year or the following year.

Preliminary information obtained on insecticide residues at the time of harvest indicate that, while those of malathion were very small, those of DDT were relatively large.

A root rot associated with the presence of *Fusarium* spp. appeared to be a contributing factor toward loss of stand of red clover plants.

THOMAS SAY FOUNDATION, VOLUME II

A supply of Volume II, *Plecoptera or Stoneflies of North America* by J. G. Needham and P. W. Claassen has recently been located. This makes all five volumes available that have been published by the Foundation. Copies of Volume II sell for $5.00 postpaid in North America and U. S. Possessions, and for $5.50 elsewhere.

Effect of Oil Spray Application Timing on Juice Quality, Yield, and Size of Valencia Oranges in a Southern California Orchard[1]

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The potential reduction of juice quality following the use of oil spray for pest control on citrus has assumed increased economic importance recently through utilization of larger volumes of the crop for juice concentrates. Yothers & McBride (1929), in Florida, Sinclair *et al.* (1941), in California, and Stofberg & Anderssen (1949), in South Africa, have found that oranges from trees fumigated with hydrogen cyanide, or left untreated, generally contained higher percentages of total soluble solids than comparable fruit treated with petroleum oil spray. Due to the resistance of scale insects, and to various economic factors, fumigation of citrus with HCN has been discontinued as a commercial practice in California.

Bartholomew *et al.* (1951), in California, and Thompson *et al.* (1951) and Harding (1953), in Florida, have concluded that the juice quality of oranges from trees sprayed with parathion is better than that of fruit from oil-sprayed trees. However, petroleum oil offers certain advantages as an insecticide for citrus pest control in California: (1) Several species of scale insects and of mites can be controlled with spray oil, often with the same application; (2) spray oils are relatively free of toxicity to man and to warm-blooded animals; and (3) they do not leave residues that constitute a toxic hazard to beneficial insect parasites and predators of citrus pests.

The relation of application timing to the reduction of juice quality of oranges from trees treated with spray oil in Florida during the period from May through November was studied by Thompson & Sites (1945). They found that the total soluble solids were as high in oranges from trees sprayed with oil in June and July as in those from untreated trees but were lower than in fruit from untreated trees when the application was made after the month of July.

The results of several studies of the effect of spray oil on the yield and size of citrus fruit are summarized and discussed by Ebeling (1950), who concludes that, when properly used, oil sprays do not necessarily reduce either yield or size of the fruit.

Early in 1951 the authors sought several Valencia orange orchards which had never been treated with spray oil or had not been sprayed with oil within a preceding period of 3 years. Discussions at that time of the orchards available in southern California led to a proposal by D. W. Tubbs, Orange County Agricultural Commissioner, that an investigation be undertaken in the Orange County orchard to study the various aspects of single applications of oil spray annually in each of the different months of the year. Preliminary observations on the effect of the various treatments on the soluble solids of the juice of the crop harvested in 1952 in this orchard were reported by Riehl & Wedding in 1953. Results of the completed 3-year investigation are reported in full in the present paper.

Materials and Methods.—A block of fairly uniform Valencia orange trees, each approximately 12 feet in height, was selected at the west side of the orchard chosen for the investigation. The soil in this orchard is sandy loam, and the grove is under a tillage program, with irrigation, fertilization, and other factors of orchard care consistent with accepted practices for the area and carried out as usual for the experimental block.

Sixteen single annual treatments were employed (see Table 1): conventional oil-spray mixture applied about the mid-point of each month of the year; oil-spray mixture plus 4 p.p.m. 2,4-D (the isopropyl esters of 2,4-dichlorophenoxyacetic acid in parts per million acid equivalent per total volume of spray mixture) applied in each of the months of July, August, and September; and a combination of fumigation with hydrogen cyanide in the month of December plus a spray treatment, as necessary, with a proprietary non-oil acaricide (ovex), a wettable powder formulation containing 50% p-chlorophenyl *p*-chlorobenzene sulfonate, at the rate of $\frac{3}{4}$ pound per 100 gallons of spray mixture. The experimental design used was a randomized block of 2 trees per plot, replicated 8 times.

In the coastal plain of southern California Valencia orange trees bloom usually in April. More than a year is required for the crop to reach maturity, and the harvest takes place from 14 to 18 months after blossom. If it were the regular practice to apply oil spray to Valencia orange trees in California in the spring of each year, there are several months in which each crop of fruit would be sprayed twice during its development. Information on the influence of such practice could be obtained for the 1952 crop by starting the series of monthly applications in March 1951.

The oil used was a proprietary California light-medium-grade (Erb 1932, Marshall 1932) emulsive spray oil having the following properties: average molecular weight, 284; unsulfonated residue, 92.5%; viscosity S.S.U. at 100° F., 67.0; composition, by weight; 2.4% aromatic carbon, 50.6% naphthenic carbon, and 47.0% paraffinic carbon; fractional distillation: 10% at 570° F., 50% at 623° F., 60% at 636° F., and 90% at 685° F. The oil was used in dilute aqueous emulsion at the rate of 1.75% (7 quarts per 100 gallons of spray mixture).

Sprays were applied manually by means of conventional orchard spray equipment. The trees were sprayed both inside and outside with a full-coverage-type application, and a sufficient volume of material was applied to each tree to wet the foliage to the point of drip. Spraying

[1] Paper No. 897, University of California Citrus Experiment Station, Riverside. Accepted for publication November 23, 1955.

The pesticide chemicals discussed may not be used unless a tolerance has been established or an exemption from the requirement of a tolerance has been granted for each specific use, irrespective of the information contained in this report.

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Table 1.—**Effect of timing of single applications annually of 1.75 per cent (conventional dosage) light-medium emulsive spray oil on juice quality of Valencia oranges in an Orange County orchard, 1951–1953.**

Treatment	Month of Annual Application	Total No. of Applications	Juice Quality Analysis				
			Per Cent Soluble Solids	Pounds Total Soluble Solids per Ton of Fruit	Per Cent Acid	Ratio Soluble Solids / Acid	Ratio Soluble Solids / Per Cent Juice
			Experiment No. 1; fruit samples taken July 23, 1951[a]				
Non-oil	—	1	12.01	128.80	1.33	9.06	53.63
Oil	March	1	11.83	131.06	1.35	9.01	54.81
	April	1	11.88	127.52	1.31	9.12	53.67
	May	1	11.98	124.17	1.35	8.79	52.53
	June	1	12.06	127.79	1.40	8.65	52.97
	July	1	12.19	131.22	1.34	9.02	53.80
Oil+2,4-D	July	1	12.04	128.45	1.37	8.94	53.28
			Experiment No. 2; fruit samples taken July 21, 1952[b]				
Non-oil		2	12.22	137.36	1.24	9.90	56.19
Oil	March	2	11.28*	125.23*	1.18	9.57	55.50
	April	2	11.34*	123.30*	1.21	9.41*	54.30
	May	2	11.73*	131.55	1.16	10.19	56.10
	June	2	11.79*	129.08*	1.17	10.08	54.41
	July	2	12.10	135.38	1.19	10.21	55.91
	Aug.	1	12.39	139.84	1.21	10.31	56.34
	Sept.	1	12.22	137.60	1.19	10.34	56.26
	Oct.	1	12.13	135.01	1.19	10.27	55.68
	Nov.	1	11.48*	129.55*	1.18	9.76	56.38
	Dec.	1	11.61*	131.58	1.19	9.86	56.55
	Jan.	1	11.73*	131.42*	1.16	10.18	56.02
	Feb.	1	11.49*	128.98*	1.19	9.69	56.13
Oil+2,4-D	July	2	12.04	134.32	1.19	10.26	55.74
	Aug.	1	12.37	138.10	1.26	9.93	55.81
	Sept.	1	11.92	135.46	1.20	9.99	55.74
L.S.D. at 5%			0.32	5.91	n.s.d.	0.45	n.s.d.
			Experiment No. 3a; fruit samples taken June 9, 1953[c]				
Non-oil	—	3	11.11	115.08	1.32	8.46	51.81
Oil	March	3	10.28*	109.04*	1.24*	8.34	53.05
	April	3	10.34*	109.48*	1.20*	8.64	52.96
	May	3	10.72*	112.43	1.26	8.51	52.47
	June	2	11.10	117.81	1.30	8.54	53.05
	July	2	11.21	117.69	1.30	8.72	51.84
	Aug.	2	11.21	115.29	1.29	8.80	51.63
	Sept.	2	11.42*	118.56	1.31	8.74	51.80
	Oct.	2	11.02	115.45	1.33	8.29	52.36
	Nov.	2	10.49*	108.34*	1.26	8.34	51.65
	Dec.	2	10.33*	110.13	1.27	8.13	53.24
	Jan.	2	10.37*	110.39	1.20*	8.64	53.26
	Feb.	2	10.46*	110.03	1.27	8.25	53.12
Oil+2,4-D	July	2	11.10	113.55	1.34	8.32	51.12
	Aug.	2	11.36	116.97	1.33	8.60	51.44
	Sept.	2	11.30	113.43	1.33	8.52	50.22
L.S.D. at 5%			0.29	5.24	0.06	0.36	1.52
			Experiment No. 3b; fruit samples taken October 5, 1953[d]				
Non-oil	—	3	12.25	127.15	1.15	10.73	51.85
Oil	March	3	11.64*	122.95	1.11	10.54	52.86
	April	3	11.34*	119.17*	1.06*	10.78	52.54
	May	3	11.39*	119.15*	1.09*	10.50	52.32

* Signifies that the mean value for the treatment differs significantly from the mean value for fruit receiving the non-oil treatment.

[a] Values listed are means of 8 samples of 20 fruits each (sizes 288 to 252, inclusive). None of the differences found were significant at the 5% level.

[b] Values listed are means of 16 samples of 20 fruits each (sizes 220 to 200, inclusive).

[c] Values listed are means of 16 samples of 20 fruits each (sizes 288 to 252, inclusive).

[d] Values listed are means of 16 samples of 20 fruits each (size 220).

Table 1.—(Continued)

Treatment	Month of Annual Application	Total No. of Applications	Juice Quality Analysis				
			Per Cent Soluble Solids	Pounds Total Soluble Solids per Ton of Fruit	Per Cent Acid	Ratio Soluble Solids / Acid	Per Cent Juice
	June	3	11.47*	119.91*	1.08*	10.66	52.27
	July	3	11.89	123.46	1.08*	10.89	51.89
	Aug.	3	11.66*	121.67	1.07*	10.90	52.17
	Sept.	3	12.01	126.23	1.08*	10.86	52.50
	Oct.	2	12.16	128.77	1.11	10.95	52.92
	Nov.	2	11.83*	124.55	1.11	10.66	52.66
	Dec.	2	11.70*	124.05	1.12	10.46	52.95
	Jan.	2	11.47*	121.93	1.08*	10.70	53.14
	Feb.	2	11.60*	121.73	1.11	10.50	52.40
Oil+2,4-D	July	3	11.83*	123.35	1.07*	11.14	52.01
	Aug.	3	11.83*	125.48	1.10*	10.81	52.99
	Sept.	3	12.42	133.95	1.12	11.09	53.89
L.S.D. at 5%			0.37	5.99	0.05	0.42	1.47

was done as soon after irrigation as possible; the application was not made when the temperature was above 85° F., or during a period of dry wind from the desert.

Fruit Sampling and Juice Analysis.—Spray applications were started in March 1951, and continued through September 1953. Fruit samples for juice-quality comparisons were taken July 23, 1951; July 21, 1952; June 9, 1953; and October 5, 1953. In July 1951, samples were taken only from the fumigated plots and from the plots which had been sprayed (see Table 1); on each of the other dates fruit samples were taken for each treatment.

Fruits for juice-quality determinations were taken at random around the periphery of the tree, within a zone 3 to 8 feet above the ground, a sample of 20 mature fruits being taken from each tree. Each time that samples were collected, a representative fruit size was chosen, the proper sizing-ring was used, and only fruits of the specified size were collected. The fruit samples were brought to the laboratory for processing. Juice was obtained by reaming the fruit manually on a small power-driven machine. Determinations of juice quality were made in accordance with the methods of analysis used by Sinclair *et al.* (1941).

Fruit Yield and Size.—The fruits of a given crop of a block of Valencia orange trees mature about the same time and are picked within an interval of a few days; it is therefore convenient to take records of yield and size at the time of harvest. The date of harvest for the experimental block was designated by the packing house according to the usual procedure for the orchard.

The 1952 crop was harvested in October. The yields were recorded as estimated field boxes per tree. The percentages of fruits in various selected size classes were ascertained by the use of a special sizing machine developed by members of the Department of Soil and Plant Nutrition and the Department of Horticulture of the Citrus Experiment Station. This machine was mounted on a trailer, taken to the experimental block, and towed through the orchard on the truck driveways used to collect the picked fruit. A representative sample of 250 fruits per tree was put into the sizing machine where the fruit passed along a horizontal roller revolving around the longitudinal axis. The diameter of the roller is graduated stepwise so that the space between the roller and a fixed vertical surface increases from that of smaller to larger fruit sizes, in conformance with the California packing-house sizes of fruits smaller than 288's, 288's, 252's, 220's, 200's, and fruit larger than 200's. These size numbers refer to the number of fruits in a packed box containing an average of 72 pounds of fruit. The diameters for the different sizes of fruit are as follows: 288's, 2.375 inches; 252's, 2.500 inches; 220's, 2.625 inches; and 200's, 2.720 inches. The fruit for each size dropped from the rollers to a chute which delivered them to respective containers. After data for yield and fruit size had been recorded, the boxes of fruit were released for transport to the packing house.

A slight modification was made in the fruit-sizing machine before the 1953 harvest. As the fruit passed along the chute from the sizing roller to a container, each one tripped a micro-switch for an electrically operated mechanical counter. This improvement greatly increased the number of fruit the machine could handle rapidly and made it possible to obtain counts of the total number of fruit harvested for each tree and the number in each of the size classes.

The customary schedule of harvest operations from June through October means that some of the crop is held on the tree after it has reached maturity and that some of the fruit drops and is lost. In these experiments mature fruits dropping from each tree were counted monthly from May through October, 1953. These records provided data on the crop for any given month during the harvest season, and on the effect of the various treatments on the drop of mature fruit during the summer.

DISCUSSION OF RESULTS.—Results of juice-quality determinations for fruit harvested in July 1951 and 1952, June 1953, and October 1953, are presented in table 1. The results of July 1951, show the effects of oil spray

applications during the spring and early summer on nearly mature or mature fruit. The results of later harvests show the effects of applications at various times of the year on developing fruit and for some of the plots, the effects of a second application within a relatively short period prior to harvest.

In the locality of the orchard used for the experiment, Valencia oranges begin to reach maturity about June and the effects of treatments which influence the quality of the juice are more likely to be critical early in the harvest season than later. With this in mind, the data for the samples collected in June 1953, were selected for use in figure 1 to illustrate the relation of application timing to the effect of oil spray on the percentage of soluble solids of the juice.

The data for yield and for fruit size for the 1952 crop are presented in table 2 and for the 1953 crop in table 3. The relation of application timing to the effect of oil spray on the total number of fruits per tree for the 1953 crop is shown graphically in figure 2.

When a portion of the crop is marketed as fresh fruit, that part of the yield may be expressed as packed boxes of fruit per tree and will be influenced by fruit size as well as by the number of fruits per tree. Actual counts of the number of fruits in each size class for the 1953 crop enabled us to express the yield per tree in terms of packed boxes. However, since oranges smaller than size 288 are seldom packed and sent to the market as fresh fruit, equivalent packed-box values were not included for the portion of the yield in the size class smaller than 288. For fruit in the size classes of 288 and larger, the numbers of packed boxes were multiplied by arbitrary factors, as follows: size 288×2, size 252×3, size 220×3, size 200×3 and sizes larger than 200×2; the factors used have a weighting function based on a market value of 1 for oranges smaller than size 288. The adjusted pack-box yield shown

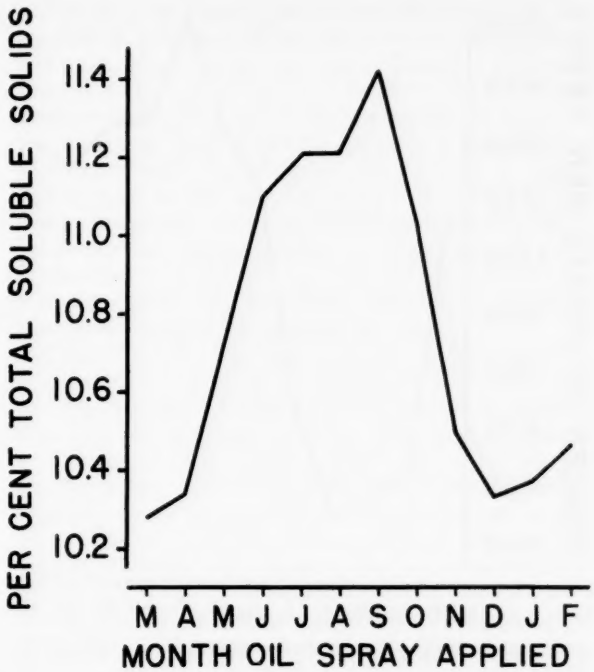

FIG. 1.—The relation of application timing to the effect of oil spray on the percentage of total soluble solids of the juice of Valencia oranges in a southern California orchard.

Table 2.—Effect of timing of single applications annually of 1.75 per cent (conventional dosage) light-medium emulsive spray oil on size and yield of Valencia oranges in experimental orchard[a].

Treatment	Month of Annual Application	Total No. of Applications	Per Cent Fruit in Size Classes						Field Boxes of Fruit per Tree
			Smaller than 288's	288's	252's	220's	200's	Larger than 200's	
Non-oil	—	2	33.7	27.4	19.9	7.9	5.2	5.9	2.84
Oil	March	2	26.9	23.5	21.3	10.9	7.2	10.3	2.71
	April	2	16.1*	16.7	22.2	12.4	11.4*	21.2*	2.17
	May	2	20.3*	24.8	26.1	11.7	8.5*	8.7	2.60
	June	2	17.2*	21.6	23.4	13.4	9.5*	14.9*	2.96
	July	2	18.6*	20.0	22.9	12.0	10.4*	16.3*	2.07
	Aug.	2	25.9*	24.5	22.5	11.8	7.4	8.0	2.42
	Sept.	2	26.2*	21.4	26.3	11.7	7.4	7.0	2.68
	Oct.	1	29.5	26.2	24.9	9.5	5.4	4.3	3.03
	Nov.	1	29.1	26.2	24.0	10.8	5.9	4.1	2.72
	Dec.	1	25.2*	24.0	25.8	11.2	7.4	6.5	3.08
	Jan.	1	30.5	24.0	24.5	9.5	7.3	4.4	3.28
	Feb.	1	27.8	23.3	24.8	10.4	6.7	7.1	3.20
Oil+2,4-D	July	2	13.1*	13.0	19.7	12.4	12.2*	29.7*	2.14
	Aug.	2	22.7*	25.3	24.9	12.5	7.7	7.0	2.66
	Sept.	2	22.3*	23.2	23.7	12.4	8.9	9.6	2.97
L.S.D. at 5%			7.4	n.s.d.	n.s.d.	n.s.d.	2.8	4.5	1.66

* Signifies that mean value for treatment differs significantly from mean value for fruit receiving the non-oil treatment.
[a] Treatment series begun March 1951 and continued through September 1952; fruit harvested in October 1952.

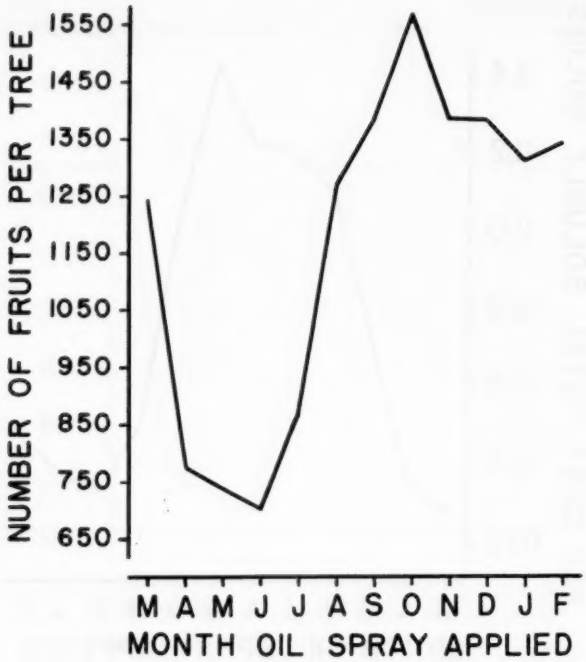

FIG. 2.—The relation of application timing to the effect of oil spray on the total number of fruits per tree for the 1953 crop of Valencia oranges in the experimental orchard.

in table 3 is the sum of the products. The relation of application timing to the effect of oil spray on the adjusted packed-box yield at the time of harvest in October 1953, is illustrated in figure 3.

Juice Quality.—Results of single annual applications of oil spray at each month of the year on the percentage of total soluble solids of Valencia orange juice are illustrated in figure 1 and show the relation of application timing as a relatively smooth curve with the highest points in late summer and the lowest points in March or April. The data given in table 1 show that the mean values for the percentage of total soluble solids for oranges from plots sprayed with oil in the late summer do not differ significantly from those for plots receiving the non-oil treatment. However, these data indicate that the percentage of total soluble solids of Valencia orange juice may be reduced significantly by oil spray application during the period of November through June.

In southern California October is an unpredictable month, which, in some years, may have weather similar to that of summer, may have strong wind from the desert with low humidity, or may bring the beginning of winter. Woglum (1940) advised citrus growers in southern California that pest control work (*i.e.*, oil spray) on oranges should be completed in September because treatment in October was accompanied, in most seasons, with more injurious effects than treatment in any other month from July to January. Our evidence indicates that the peak of the curve of figure 1 occurs before October and that the curve begins to descend during that month.

It is preferable to pick the mature fruit prior to spraying with oil; this practice avoids inhibition of degreening in the fruit rind either on the tree or during the packing process and avoids any deleterious effect on the quality

Table 3.—Effect of timing of single applications annually of 1.75 per cent (conventional dosage) light-medium emulsive spray oil on size and yield of Valencia oranges in experimental orchard.[a]

Month of and Total No. of Annual Applications	Per Cent Fruit in Size Classes						Total Number Fruits per Tree Oct. '53	Field Boxes' Fruit per Tree Oct. '53	Fruits Dropped per Tree May '53 to Oct. '53	Mean Adjusted Packed-Box Yield (Sum per Tree)	
	Smaller than 288's	288's	252's	220's	200's	Larger than 200's				June 1953	Oct. 1953
					Non-oil						
Dec. 3	69.5	21.4	7.0	1.6	.3	.1	1,515.8	5.94	170.4	4.05	3.60
					Conventional Oil Spray Mixture						
Mar. 3	63.6	23.3*	8.9	3.2	.5	.3	1,241.8*	4.95*	145.3	3.72	3.23
Apr. 3	53.6*	26.5*	12.9*	4.6*	2.2*	.6	775.2*	3.18*	116.3*	3.42	2.88
May 3	41.4*	28.6*	17.7*	7.0*	3.3*	1.9*	738.3*	3.80*	141.1	4.74	3.98
June 3	28.4*	23.5*	20.2*	12.2*	8.8*	7.2*	701.9*	3.19	171.1	5.18*	3.90
July 3	30.6*	29.2*	22.6*	11.5*	5.2*	2.6*	874.7*	4.05*	195.9	6.14*	4.72*
Aug. 3	55.1*	26.6*	12.1*	4.4*	1.5	.5	1,270.3*	4.91*	252.2*	5.34*	4.30
Sept. 3	53.1*	26.6*	12.8*	4.7*	1.9*	1.2	1,384.8	5.59	271.9*	5.84*	4.66
Oct. 2	56.1*	25.6*	12.7*	3.9*	1.2	.6	1,566.8	6.13	260.4*	6.35*	5.29*
Nov. 2	56.7*	26.9*	11.8*	3.4	.9	.6	1,384.0	5.77	198.6	5.41*	4.63
Dec. 2	58.9*	25.3	11.1*	3.4	.9	.4	1,382.4	5.55	193.2	5.01	4.27
Jan. 2	55.0*	27.2*	12.2*	3.8*	1.4	.4	1,312.3*	5.25	162.2	5.33*	4.66*
Feb. 2	59.7*	25.6*	10.6*	3.1	.8	.3	1,340.8	5.36	192.0	4.82	4.13
					Conventional Oil Spray Mixture plus 2,4-D						
July 3	23.8*	24.3*	24.1*	15.9*	7.5*	4.5*	953.9*	4.80	150.4	7.93*	6.65*
Aug. 3	51.8*	27.4*	13.5*	4.9*	1.8*	1.0	1,204.7*	4.76*	219.8*	5.47*	4.48
Sept. 3	57.4*	25.5*	11.9*	3.5	1.2	.7	1,215.5*	5.07	174.0	5.01	4.30
L.S.D. at 5%	6.8	2.9	2.7	2.0	1.5	1.4	183.1	.93	35.4	1.05	1.05

* Signifies that mean value for treatment differs significantly from mean value for fruit receiving the non-oil treatment.
[a] Treatment series begun March 1951 and concluded in September 1953; fruit harvested in October 1953.

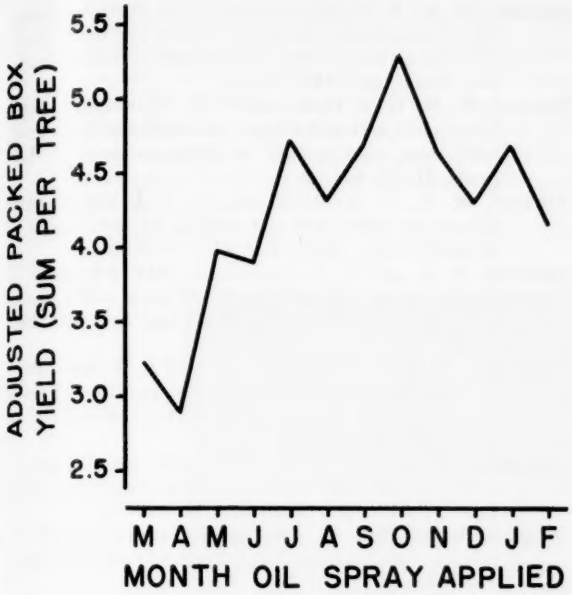

FIG. 3.—The relation of application timing to the effect of oil spray on the adjusted packed-box sum of Valencia oranges per tree for the experimental orchard at the time of harvest in October 1953.

of the juice of nearly mature fruit. The data on table 1 indicate that the juice quality of the 1951 crop was not reduced by spraying the trees as the fruit neared maturity. But comparison of the two sets of samples taken in 1953 shows that total soluble solids increased more in fruit from the non-oil plots from June to October 1953, than in comparable fruit from the plots in which the crop of fruit had been sprayed with oil twice.

In table 1 differences in percentage of acid were not significant for the 1952 crop, and the single significant difference in the ratio of soluble solids to acid seems to be associated more with the reduction in soluble solids than with the effect of oil spray in April on the percentage of acid. The data for 1953 show that significant reductions of the percentage of acid occurred in fruit treated with oil in the winter months and particularly in treatments in which the application timing was such that oil spray was applied twice during the development of the crop; however, the various ratios of soluble solids to acid did not differ significantly from the value for the non-oil treatment.

Percentage of juice does not seem to be influenced appreciably by varying the application timing of oil spray.

Yield.—Differences in fruit yield between the non-oil plots and those sprayed with oil during the period from August through December are not significant for the total number of oranges per tree for the 1953 crop. However, the curve presented in figure 2 shows a progressive decline from the high for late summer to the low for oil spray applications in June, and by the month of January the mean number of fruits for plots treated with oil spray was significantly lower than that for plots given the non-oil treatment.

The practical importance of the influence of fruit size on yield is indicated by the values for adjusted packed box sums. The shape of the curve in figure 3 is similar, in general, to that of the curve in figure 2. There is a progressive decline from a high for late summer to a low for the month of April. However, in table 3 the adjusted packed-box sums for plots sprayed with oil in March and in April are the only values lower than that for the non-oil treatment. Even these differences are not significant, whereas the mean values for the number of fruits per tree for 7 of the months and for field boxes per tree for 6 of the months are significantly lower than the mean values, respectively, for the non-oil treatment.

Effect of 2,4-D.—The data of table 3 indicate that the addition of 4 p.p.m. of the isopropyl esters of 2,4-D to dilute aqueous oil spray mixtures applied to Valencia oranges in the summer appears to offer some advantage as a means of reducing the drop of mature fruit during the succeeding crop season, but the advantage was not sufficient to be reflected as an increase in any of the expressions of yield. The addition of 2,4-D did not provide any benefits with respect to the percentage of total soluble solids or to the number of fruit borne by the tree.

Fruit Size.—The data of tables 2 and 3 for percentage of fruit in size classes show that oranges from trees sprayed with oil are larger than those from trees which received the non-oil treatment.

Stewart *et al.* (1952) observed that the size of Valencia oranges could be increased by applications of 2,4-D during the first 16 weeks after blossom but that the response diminished with time during this period. Stewart *et al.* (1952) observed that spray oils applied to orange trees in the spring increased the size of the fruit but reduced the yield per tree and that this effect was intensified by the addition of 2,4-D to the spray mixture.

The data of tables 2 and 3 indicate that the presence of spray oil on the Valencia orange tree in the spring affects the function of the tree in some way which culminates in a much smaller number of larger oranges; however, the net result in terms of yield is less.

Proper Application Timing.—Since oil spray is applied to citrus trees for pest control, timing of the application should be governed primarily by the "condition" of the pests present, to obtain the maximum control efficiency. Experience with the scale insect and mite pests present currently in citrus orchards of the coastal plain of southern California indicates that late summer is very likely to be favorable for control of these pests by means of oil spray. The results obtained show that reductions in juice quality or yield of Valencia oranges are less likely to occur from applications of oil spray in the late summer than at any other time of the year.

SUMMARY AND CONCLUSIONS.—The effect of single annual applications of oil spray at each month of the year on the percentage of total soluble solids of the juice and on the yield of Valencia oranges in southern California may be shown as a relatively smooth curve with the highest points in the late summer and the lowest points in March or April.

The percentage of total soluble solids of the juice may be reduced significantly by applications of oil spray during the period from November through June.

Comparisons of Valencia oranges treated with oil spray

in the late summer with those fumigated with HCN and sprayed with a non-oil acaricide, as required, show that (1) differences in percentages of total soluble solids of the juice were not significant; (2) the adjusted packed-box sum of fruit per tree was greater for the oil-sprayed plots than for the non-oil-sprayed plots; and (3) the fruits from the trees sprayed with oil were larger.

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Meadow Spittlebug and Peach Gumosis[1]

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For a long time, certainly as far back as the early 1920's, the author has observed a distinctive type of injury on peaches, in which gum extrudes from the fruit in droplets from minute punctures. Very frequently, with rapid growth following wet weather, this exudation assumes a stringlike crystalline form from one-half to a full inch in length (Figure 1).

In grading the crop, since this damage is seldom plentiful, it has been grouped with that resulting from the attack of various peach insects, including the plum curculio (*Conotrachelus nenuphar* (Hbst.)), oriental fruit moth (*Grapholitha molesta* (Busck)), tarnished plant bug (*Lygus lineolaris* (P. de B.)), and several stink bugs of the genus *Euschistus*. Usually, it has been placed under "catfacing," attributable to feeding by the hemipterous forms indicated above; but, incorrectly so, since no typical rough scar subsequently develops. The most recent report on this subject is that of Chandler (1955).

A confusingly similar discharge, sometimes referred to as "gum-flow," has been associated with the fruit-infection phase of bacterial spot of peach, a disease caused by *Xanthomonas pruni* (E. F. Smith) Dowson; see Dunegan (1932) and Hopperstead & Manns (1945).

Within the past decade, the particular type of gumosis considered herein has become increasingly abundant. Although not commercially important in well-sprayed orchards, growers are naturally curious about its origin. Its appearance and prevalence have seemed correlated with expanding populations of the meadow spittlebug (*Philaenus leucophthalmus* (L.)). Also, the time of injury has coincided with the maturity and migration of the insect from alfalfa, clover and other hosts of the nymphal stage. From 1946 to 1955, inclusive, the earliest observed date has been June 12 (1946) and the latest, June 20 (1950).

The roving propensity and flight habits of this species have long been recognized, and have been discussed by Osborn (1916, 1939) and by Weaver & King (1954). It is no stranger in peach plantings, its possible role in the transmission of yellows (*Chlorogenus persicae* var. *vulgare* Holmes) having been investigated by Kunkel (1933) with negative, and by Manns (1939, 1942) with questionable results. More recently, Putman (1953) reported on a "spectacular concentration of adults" along the Lake Ontario shore in the vicinity of Vineland Station on July 5, 1945. In a personal communication, dated September 2, 1955, he stated that, a few days after this "remarkable mass invasion" of that orchard area, strings

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of gum (similar to those previously described) were noticed. However, they soon disappeared without leaving any permanent injury; furthermore, in repeated tests with caged adults, this effect has not yet been duplicated. Weaver (Ohio Station) reported (letter dated August 22, 1955) that he and Rings (loc. cit). have established the fact that the adults feed on peach terminals, but did not test the actual peaches.

TRAP COLLECTIONS.—In 1955, for the purpose of determining the movement and activity of meadow spittlebug adults, 90 sticky-board traps were placed in two orchards near Camden, Delaware. Such traps have been used in scouting for pear psylla (Kaloostian & Yeomans, 1944) and in leafhopper migration studies (Tomlinson *et al.* 1950, Hutchinson 1955). In this instance, they were pieces of $\frac{1}{4}$-inch plywood ($5\frac{1}{4}'' \times 9\frac{1}{2}''$), dipped twice in traffic-yellow paint, and uniformly coated (3/32″) on both sides with *Pestix*, a tree-banding paste once manufactured by the Sherwin-Williams Company of Cleveland, Ohio. These small boards had a $\frac{1}{4}$-inch hole at the top-center, and were suspended beneath the peripheral canopy of the trees from limbs ranging from 46 to 77 inches above the ground (average, 63″), by means of a 5-inch tether swivel-snap. No correlation was found between height and catch.

On May 3, 30 traps were placed at random in each of two 14-year-old Golden Jubilee and Georgia Belle blocks (Clark orchard), separated by a dual highway; and 15, in each of two adjacent rows in a 16-year-old Halehaven-Elberta planting (Lord orchard). They were removed on July 18, July 25 and August 1, respectively, as these varieties approached maturity.

Records (Table 1) for the 13 weeks of trap operation reveal an amazingly-large population of adult spittlebugs in these orchards. The earliest mature forms of this species were encountered (by Dr. H. E. Milliron) in alfalfa and clover fields of the State on May 16th. They were collected first by the traps during the week of May 17–23; were present in greatest numbers between June 21 and 26 (116 or 23% of total); and had practically disappeared by the last of July.

This three-month period was relatively hot and dry (average temperature 72.6° F., or 5.1° above normal; total precipitation 9.53 inches, or 2.66 inches below normal). On 5 of the 8 days, June 6 to 13, inclusive, there was rainfall amounting to 4.68 inches (49% of the total for the entire period). Apparently, this delayed the peak of abundance about 2 weeks.

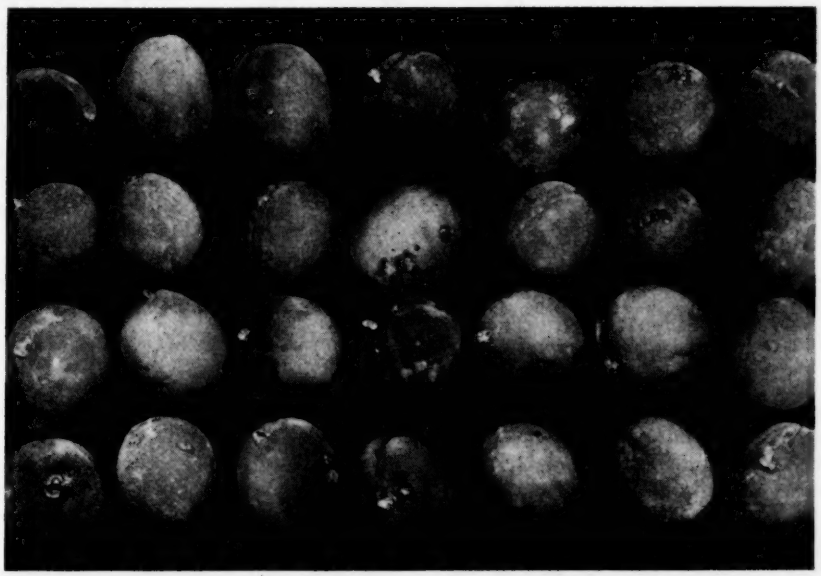

FIG. 1.—Peach gumosis resulting from feeding by meadow spittlebug adults.

Despite the fact that the adhesive coating on the traps was subjected to almost 10 inches of rain and the forceful sprays of at least seven fungicide-insecticide applications, they were still operating satisfactorily when removed. A total of 509 adults were captured, or 0.06 per square-inch of exposed surface. The averages for the different varieties in the two orchards were essentially the same (Lord's—9.9 and 11.1 for Halehaven and Elberta; Clark's—3.4 and 3.1 for Golden Jubilee and Georgia Belle).

GUMOSIS.—Weekly examinations of both sprayed and unsprayed peaches in several orchard districts of Delaware revealed first gumosis on June 13. It had become rather common by July 14, and the extremely grotesque forms were noted, as usual, during late July and early August.

CAGE TESTS.—In 1950, a few adult spittlebugs, confined in small "sleeve cages" on peach terminals, had failed to produce gumosis. In 1955, three cheesecloth-covered cages (20″×20″×20″) were installed in that many Elberta trees in the Lord Orchard. Both enclosed foliage and fruit were insect-free and the latter (13 in Cage 1; 12 in Cage 2; and 15 in Cage 3) apparently uninjured in any way. Each cage received 75 adults on June 13, 20 and 27, or 225. By July 11, 15 per cent of the peaches (15% in Cage 1; 25% in Cage 2; and 7% in

Table 1.—Summary of adult spittlebug collections in peach plantings at Camden, Delaware, 1955.

Period[a]	Lord Orchard		Clark Orchard		Number of Adult Spittlebugs	Percentage of Total	Rainfall in Inches[c]	Percentage of Total for Period
	Halehaven	Elberta	Golden Jubilee	Georgia Belle				
May 3–9	0	0	0	0	0	0.0	0.00	0.0
10–16[b]	0	0	0	0	0	0.0	0.58	6.1
17–23	0	1	0	0	1	0.2	0.04	0.4
24–30	12	14	13	6	45	8.8	1.22	12.8
31–June 5	17	16	16	12	61	12.0	0.39	4.1
June 6–13	8	7	15	22	52	10.2	4.68	49.1
14–20	21	16	13	9	59	11.6	0.75	7.9
21–26	45	42	19	10	116	22.8	0.32	3.4
27–July 4	9	34	6	3	52	10.2	0.00	0.0
July 5–10	18	17	8	14	57	11.2	0.01	0.1
11–17	13	7	12	5	37	7.3	0.00	0.0
18–24	6	9	—	11	26	5.1	1.28	13.4
25–31	0	3	—	—	3	0.6	0.26	2.7
Total	149	166	102	92	509	100.0	9.53	100.0
Average per Trap	9.9	11.1	3.4	3.1				

[a] Sticky-board traps placed in all plantings, May 3; removed from Golden Jubilee, July 18; Georgia Belle, July 25; and Halehaven and Elberta, August 1.
[b] First adults collected on alfalfa and clover, May 16.
[c] From Climatological Data, Maryland and Delaware, May to July, inclusive, 1955; Dover Station (3 to 5 miles from the collection orchards).

Cage 3) showed typical gumosis. No such effect was observed, then or subsequently, on any peaches in these three trees. In fact, on this same variety, it required 1 hour and 35 minutes on July 14 and 1 hour and 20 minutes on August 1 to locate 28 damaged fruits for preservation.

Peaches, both from the cages (July 11) and at large (July 14; average size, 1-11/16″×1-9/16″) showing gumosis, were cultured under the direction of Dr. J. W. Heuberger, Plant Pathologist, and found to be disease-free. The last stink bugs (*Euschistus tristigmus* (Say)) were collected by jarring in this planting on April 25 (none were captured by the traps) and the last overwintered plum curculio adults, on May 2 (only eight, captured by the traps).

Miscellaneous Material Collected.—Naturally, many insects other than adult spittlebugs were captured by the sticky-board traps, some in large numbers. Because of their struggles to escape from the adhesive and consequent mutilation, certain identification *in situ* was usually impossible. Also, successful removal of all specimens still intact was such a time-consuming task as to be impracticable. Some of interest, however, were retained; and the following determinations were either made or confirmed by Dr. H. E. Milliron.

Generally speaking, species were conspicuous by their presence or absence. Only a few Lepidoptera were caught —no oriental fruit moths (*Grapholitha molesta* (Busck)), and but occasional European corn borer (*Pyrausta nubilalis* (Hbn.)) and armyworm (*Pseudaletia unipuncta* (Haw.)) adults in early June and mid-July, respectively.

Both Hymenoptera and Diptera were present in some abundance—two oriental fruit moth parasites (*Macrocentrus* sp. and *Cremastus* sp.) were noted; and *Chrysops* sp. and *Tabanus* sp. were present during their normal period of activity. Lacewing-flies (Neuroptera, Chrysopidae) were very common, with 473 counted on the 30 Halehaven-Elberta traps on July 14.

Hemiptera were scarce—no Mirids or Pentatomids and but a single Reduviid, the wheelbug (*Arilus cristatus* (L.)). Homoptera, on the contrary, were regularly recorded—although the meadow spittlebug was the only Cercopid, there were nine Cicadellids, with *Macropsis trimaculata* (Fitch), the species involved in the transmission of peach yellows, lacking, as follows: *Idiocerus alternatus* Fitch, *Aulacizes irrorata* (F.), *Oncometopia undata* (F.), *Graphocephala versuta* (Say), *Draeculacephala portola* Ball, *Gypona* sp., *Norvellina seminuda* (Say), *Paraphlepsius irroratus* (Say) and *Colladonus clitellarius* (Say).

Coleoptera, likewise, were common, with the Coccinellidae well-represented but the Mexican bean beetle (*Epilachna varivestis* Muls.) absent. The following 19 species were included: *Ceratomegilla fuscilabris* (Muls.), *Hippodamia convergens* Guer., *Adalia bipunctata* (L.), *Anatis quindecimpunctata* (Oliv.), *Psyllobora vigintimaculata* (Say), *Brachyacantha ursina* (F)., *Ctenicera* sp. (119 specimens of this Elaterid counted on the 30 Halehaven-Elberta traps on July 14), *Phymatodes amoenus* (Say), *Elaphidion parallelum* (Newn.), *Neoclytus acuminatus* (F.), *Crioceris asparagi* (L.), *Criocerus duodecimpunctata* (L.), *Cerotoma trifurcata* (Forst.), *Galerucella nymphaeae* (L.), *Diabrotica undecimpunctata howardi* Barb., *Acalymma vittata* (F.), *Disonycha pennsylvanica* Illig, *Metriona bicolor* (F.) and *Cantharis rectus* Melsh. In the Rhynchophora, only *Hypera postica* (Gyll.), *Conotrachelus nenuphar* (Hbst.) and *Cryptorhynchus pumilus* (Bob.) were captured.

These data seem worthy of record. In addition to the meadow spittlebug, adults of several important crop pests, including the European corn borer, armyworm, both species of asparagus beetles, bean leaf beetle, both species of cucumber beetles, golden tortoise beetle,

alfalfa weevil and plum curculio, were collected. This fact warrants greater utilization of the sticky-board trap as a device for studying insect migration.

Summary.—For many years, a distinctive type of injury has occurred on peaches, in which gum extrudes from the fruit in droplets from minute punctures. Very frequently, with rapid growth following wet weather, this exudation assumes a string-like crystalline form from one-half to a full inch in length. Since seldom plentiful and, therefore, not commercially important, this damage usually has been grouped with that resulting from the attack of various peach insects. Sometimes, it has been confused with gum-flow, a discharge associated with the fruit-infection phase of bacterial spot of peach.

Within the past decade, this particular type of gumosis has become increasingly abundant. Its appearance and prevalence have seemed correlated with expanding populations of the meadow spittlebug (*Philaenus leucophthalmus* (L)). Also, the time of observed injury in Delaware (from 1946 to 1955, inclusive, ranging between June 12 and 20) has coincided with the maturity and migration of the insect from alfalfa, clover and other hosts of its nymphal stage.

In 1955, the movement of this species into peach (Golden Jubilee, Georgia Belle, Halehaven and Elberta) plantings in the Camden area was determined by means of sticky-board traps. Adults were collected first during the week of May 17 to 23; were present in greatest numbers between June 21 and 26; and had practically disappeared by the last of July.

First gumosis was encountered on June 13; it had become rather common by July 14; and the extremely grotesque forms were noted, as usual, during late July and early August.

Identical characteristic injury was produced by caged adults. Therefore, this insect appears to be definitely incriminated as the agent responsible for gumosis.

The fact that, in addition to the meadow spittlebug, adults of several important crop pests were captured by the sticky-board traps emphasizes the value of such traps in insect-migration studies.

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An Evaluation of Newer Insecticides for Control of DDT-Resistant Cabbage Loopers[1]

F. L. McEwen and G. E. R. Hervey

When DDT became available as an agricultural insecticide it was soon learned (Swingle & Mayer 1944, Smith & Harrison 1944) that this material was highly toxic to cabbage caterpillars. Later work (Apple 1945, Huckett 1946, 1949, Wene 1949) confirmed these early findings, and the botanical and arsenical insecticides formerly used in cabbage caterpillar control were replaced by DDT and related chlorinated hydrocarbons. McEwen & Chapman (1952) reported that by 1951 the imported cabbageworm had developed resistance to DDT in certain areas in Wisconsin and this report was followed by those of Hervey & Swenson (1953), Hayslip *et al.* (1953), and Wheatley (1955), indicating that DDT was becoming less effective in controlling this species in western New York, Florida and Connecticut, respectively. DDT resistance in the cabbage looper was likewise developing. Hervey & Swenson (1953) reported that while an increased dosage of DDT was still adequate for control of the imported cabbageworm, more than 25 per cent of cabbage loopers survived on foliage treated with an 8% DDT dust. Wene (1954) was unable to obtain good control of the cabbage looper with DDT during hot weather, even with a 10% dust, while in cooler weather a 5% dust gave excellent control of a low infestation. Toxaphene, isodrin, endrin and dieldrin appeared promising as substitute materials by this worker.

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In western New York, the imported cabbageworm (*Pieris rapae* (L.)), the cabbage looper (*Trichoplusia ni* (Hbn.)), and, to a lesser extent, the diamondback moth (*Plutella maculipennis* (Curt.)) are present as pests of cruciferous crops, and DDT at $\frac{1}{4}$ or $\frac{1}{2}$ pound of actual toxicant per acre gave excellent control of these insects during the early years of its use.

As the effectiveness of DDT in controlling this pest complex declined, growers were able to obtain adequate control by increasing the dosage of toxicant but by 1953 the cabbage looper had become so resistant to DDT that such a program would no longer suffice (Hervey & Swenson 1953). During 1954, populations of the cabbage looper were extremely low in western New York and although the imported cabbageworm was somewhat a problem, growers of cruciferous crops following a DDT spray program were able to market a relatively clean product. In 1955, however, cabbage loopers were numerous and with DDT appearing no longer effective against this species (Table 1) laboratory and field investigations were undertaken to study the degree of DDT resistance present and to determine what insecticides might be used to control DDT-resistant cabbage loopers.

METHODS.—For the laboratory test, loopers were collected in a field of cabbage in Cortland County. Although previously sprayed several times with DDT and lindane, 3 to 5 cabbage loopers per plant, in various instars, could still be found. In testing these insects, broccoli leaves were used as the feeding surface to which treatments were applied. These leaves were placed erect with their stems in wet sand in 4-inch pots, one leaf per pot. They were than placed on a turntable and sprayed with a paint spray gun to the point of run-off. Spreader-sticker (B-1956, Rohm & Haas) was added to all treatments. Seven leaves were sprayed with each treatment tested. After the leaves were air-dried, each was inclosed in a ventilated plastic cage 2 inches in diameter and 8 inches high, and five larvae were placed in each cage. The sand in the pots was kept wet to prevent the leaves from wilting, and the number of living, dead and pupating larvae was counted after 24 and 44 hours.

In the field tests, a low-gallonage, tractor-mounted type sprayer (Hervey & Gunkel 1952) was employed. This machine was equipped with four No. 8001 *Teejet* nozzles per row, operated at a pressure of 80 pounds and driven at such a rate as to deliver 26 gallons per acre. Three spray tests were conducted on a grower's cabbage fields. Plots consisted of 2 or 4 rows approximately 250 feet long and each treatment was replicated 6 times in a randomized block design. Insecticide formulations tested were emulsifiable concentrates of Diazinon, DDT, dieldrin, endrin, isodrin, parathion and toxaphene, technical Shell OS-2046 and a wettable powder of Bayer 17147. Two to four days after spray application the five plants showing the greatest amount of foliage injury were selected in each plot, dissected, and the number of living larvae found recorded.

RESULTS.—The laboratory data are presented in table 2 and show that of the materials tested only Shell OS-2046 and endrin were effecting a high degree of mortality. DDT was relatively ineffective and mortality of cabbage loopers was not greatly increased by a four-fold increase

Table 1.—The decline in effectiveness of DDT against the cabbage looper in field tests in western New York, 1944–55.

Actual DDT Pounds/Acre	Per Cent Cabbage Looper Control		
	1944	1953	1955
0.125	94	38	—
.25	95	66	—
.5	99	60	45
1	—	77	55
1.5	—	76	—
Average larvae per plant (untreated)	5	20	30

Table 2.—Results of laboratory tests against cabbage looper larvae. Geneva, N. Y., Aug. 15, 1955.

Toxicant	Ratio Actual/ Water	Insects Surviving 44 Hours After Treatment[a]	
		No. Larvae	No. Pupae
DDT	1:800	18	9
DDT	1:1600	21	10
DDT	1:3200	22	13
Parathion	1:1600	12	6
Shell OS-2046	1:1600	6	0
Endrin	1:3200	5	3
Bayer 17147	1:800	15	2
Check (spreader-sticker)	1:25000	27	8

[a] Out of 35 larvae tested.

Table 3.—Cabbage looper control in field tests following application of various insecticides. Geneva, N. Y., 1955.

Material	Actual Toxicant Pounds /Acre	Mean No. Living Larvae per 5 Plants Experiment[a] 1	2	3	Mean Control (Per Cent)
Endrin	0.5	20	13	6	91.6
	0.25	—	24	—	81.7
Isodrin	1.0	24	14	—	89.8
	0.5	—	22	—	83.2
Shell OS-2046	1.0	—	18	—	86.3
	0.5	51	21	—	81.6
	0.25	84	—	—	65.7
Parathion	1.0	—	49	—	62.6
	0.5	97	52	50	52.9
DDT	1.0	111	—	—	54.7
	0.5	127	80	42	45.0
Diazinon	0.5	156	—	—	36.3
Bayer 17147[b]	1.0	186	—	—	24.1
Dieldrin	0.5	—	—	31	61.5
Toxaphene	2.0	—	—	46	43.8
Toxaphene plus Parathion	2.0 0.5	—	—	20	75.9
DDT plus Parathion	0.5 0.5	—	87	44	39.4
Check		245	131	81	
L.S.D. at 5% level		33.3	21.0	13.4	
1% level		44.8	28.3	18.2	

[a] 1. Spray applied Aug. 22, counts made Aug. 24 and 25.
2. Spray applied Aug. 26, counts made Aug. 29.
3. Spray applied Sept. 15, counts made Sept. 19.

[b] Some nozzle clogging; count may not be reliable.

in rate of application. Parathion and Bayer 17147 were equal in toxicity at the dosage tested, neither inducing high mortality. Feeding was moderate to heavy on foliage treated with insecticides other than parathion, but where this toxicant was applied little feeding occurred.

Results of field tests are summarized in table 3. These data indicate that endrin, isodrin and Shell OS-2046 were equally effective in cabbage looper control, although twice as much toxicant was required in the case of the latter two materials. Parathion did not give satisfactory control nor did toxaphene; however, when these two toxicants were combined a higher degree of control was obtained. Some foliage injury (slight to moderate browning on the edge of leaves) resulted from application of toxaphene alone or in combination with parathion. DDT at 0.5 pound per acre gave less than 50% control of the cabbage looper in each of the three tests and control was little improved when the dosage was increased or when it was used in combination with parathion. Diazinon, dieldrin and Bayer 17147 did not give practical control in these tests.

Discussion.—The cabbage looper has become so resistant to DDT in western New York that control with it, even at greatly increased dosages, is no longer satisfactory. The data presented represent mortality obtained with a single application to an established infestation. While control is undoubtedly inferior to that possible using the same toxicants in a properly timed spray schedule, the relative effectiveness of the insecticides is clearly indicated. Whether or not high temperature was a significant factor in the poor response to DDT applications (Wene 1954) is not evident, as the maximum daily temperature was in excess of 75° F. during each spray test herein reported. Information available (Wigglesworth 1955) would indicate that for certain insect species, increased temperatures, within limits, increase an insect's resistance to poisoning with DDT. This increased resistance, however, may be outweighed since the insect's greater activity at higher temperatures will expose it to more toxicant. In 1944 when DDT gave excellent control of the cabbage looper (Table 1) the mean temperatures during July and August at Geneva were 73.3 and 74.0° F., respectively, while for the same months in 1955 values of 76.4 and 73.9 were obtained.

Newer insecticides which gave good control of the cabbage looper were endrin, isodrin and Shell OS-2046. Toxaphene and dieldrin, reported by Wene (1954) as effective, did not give sufficient control to warrant further investigation.

Summary.—The cabbage looper (*Trichoplusia ni* (Hbn.)) can no longer be satisfactorily controlled with DDT in western New York. Of the materials tested endrin, isodrin and Shell OS-2046 gave excellent control while dieldrin, toxaphene, Bayer 17147, parathion, Diazinon and a mixture of DDT and parathion did not give practical control. A combination of parathion and toxaphene reduced looper populations 75% in these tests.

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Studies of Four Summer Hosts of the Beet Leafhopper[1]

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The suitability of four summer host plants—halogeton, kochia, Russian-thistle, and smotherweed—as reservoirs of the curly-top virus and for the reproduction of the beet leafhopper (*Circulifer tenellus* (Bak.)) was studied at the Twin Falls, Idaho, laboratory and in some of the leafhopper-breeding areas in Idaho and surrounding States from 1938 to 1954. These four hosts are foreign weeds of the family Chenopodiacea.

Halogeton (*Halogeton glomeratus* (Bieb.) C. A. Mey.), a native of central Asia, was first reported as a host by Douglass *et al.* (1944). Cook & Stoddart (1953) indicated that it thrives where the native plant cover is thin or low in vigor and does well on sagebrush (*Artemisia tridentata* Nutt.) and shadscale (*Atriplex confertilfolia* (Torr.) Wats.) ranges. Zappettini (1953) gave the characters that distinguish halogeton from the other Chenopodiacea often confused with it. A close resemblance has been noted between halogeton and Russian-thistle in certain stages of growth (Fig. 1).

Kochia (*Kochia scoparis* (L.) Schrad.), which was introduced from Eurasia and used as an ornamental, has escaped from cultivation. The writers have observed this plant in the leafhopper-breeding areas within cultivated districts in Idaho, Montana, and Wyoming, and it does well under conditions favorable for smotherweed. Buchholtz *et al.* (1954) indicated that kochia is a drought-resistant weed, which has recently spread rapidly in the Plains States. Gates (1941) gave a description of kochia and its habits. The studies reported here on this plant were conducted in the laboratory, since pure stands have not become sufficiently abundant over the area. Kochia resembles and is often confused with smotherweed (Fig. 2).

Russian-thistle (*Salsola kali* var. *tenuifolia* Tausch) was introduced in flaxseed from Europe into South Dakota about 1873 and has spread throughout the leafhopper-breeding area. Descriptions of this plant and the conditions favorable for its growth have been given by Gates (1941) and Stevens (1943).

Smotherweed (*Bassia hyssopifolia* (Pall.) Kuntze), a native of the Caspian Sea region of Asia, was found in the United States at Fallon, Nevada, in 1919 and has spread over the Western States. It grows well in alkaline soil of cultivated fields and waste places. High populations of the beet leafhopper on smotherweed in Idaho were recorded by Haegele (1932), and the plant is becoming widely distributed where soil conditions are favorable for its growth.

Laboratory Studies.—Plants of these four summer hosts were grown in flower pots and flats. A single branch was caged, or a cage was placed over one or more plants. Ten viruliferous female beet leafhoppers were introduced into each cage and held for about 14 days, or until the eggs deposited on the foliage had hatched. The nymphs were reared to the fourth or fifth instar and then tested for curly-top infection according to the method described by Wallace & Murphy (1938), in which each nymph was caged for 7 to 10 days on a cotyledon sugar beet of the R. and G. Old Type, a variety very susceptible to curly top. The final reading of curly-top symptoms was made according to Giddings' (1938) system 30 days after the start of the test.

The four plants produced about equally high leafhopper populations in the cages. Douglass *et al.* (1944) has shown that halogeton could produce 572 leafhoppers per square foot of soil surface in the green house. The percentage of nymphs acquiring the virus from these hosts ranged from 0 on smotherweed to 21 on kochia (Table 1). Since the virus does not pass from the egg to the young nymph, it is evident that some of the nymphs acquired the virus from these hosts.

In one of the tests on kochia, 82 per cent of the leafhoppers were viruliferous, which was comparable with 85 to 90% found in tests on curly-top-infected spinach and sugar beets. Severin & Freitag (1934) found that kochia plants growing on the University campus at Davis, Calif., were naturally infected and that 40 per cent of them were killed by curly top.

About 7,000 adult beet leafhoppers collected from pure stands of Russian-thistle were also tested for curly-top infection. The percentage carrying the virus ranged from 2 in 1943 to 31 in 1947, with an average of 10% (Fig. 3). In 1941 and 1947 the percentages were 29 and 31, as compared with 61 and 43 in the previous springs among leafhoppers collected from sugar-beet fields. Some of the leafhoppers collected from the Russian-thistle may have come recently from infected beet fields. Wallace & Murphy (1938) indicated that Russian-thistle was not a favorable plant for the increase and distribution of the curly-top virus.

Of 380 leafhoppers collected from pure stands of smotherweed, 0.3% carried the virus. Some of the infected leafhoppers may have recently moved from other hosts, since none of the leafhoppers reared on this host were infected.

Field studies.—The field studies were conducted in two districts—from 1943 to 1950 in the Idaho-Nevada-Utah district along the roads through Malta and Strevell in Idaho; Park Valley and Lucin in Utah; and Montello, Wells, Elko, Contact, and San Jacinto in Nevada; from 1942 to 1951 in the Nyssa district, which extended from Boise, Idaho, west to Brogan, Oregon, and from Weiser, Idaho, south to Grand View, Idaho.

Russian-thistle and smotherweed were studied at all localities, but halogeton did not occur in the Nyssa district. The host plants were sampled at approximately 15 stops distributed throughout each district, and only

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FIG. 1.—Branches of halogeton (left) and Russian-thistle (right), summer hosts of the beet leafhopper.

pure stands were examined. The ½-square-foot fork described by Lawson *et al.* (1941) was used to determine the leafhopper population, and 10 samples were taken at each stop. All nymphs and adults were recorded for each sample.

In the Nyssa district the acreages of Russian-thistle and smotherweed were determined and converted to the basis of a 100% stand. The average number of leafhoppers per square foot was used to compute the total populations of these two hosts. Figures are not available for the acreage of these hosts in the Idaho-Nevada-Utah district.

The relative importance of these hosts in producing large populations of beet leafhoppers is shown in tables 2 and 3. The average populations on Russian-thistle and

FIG. 2.—Branches of kochia (left) and smotherweed (right), summer hosts of the beet leafhopper.

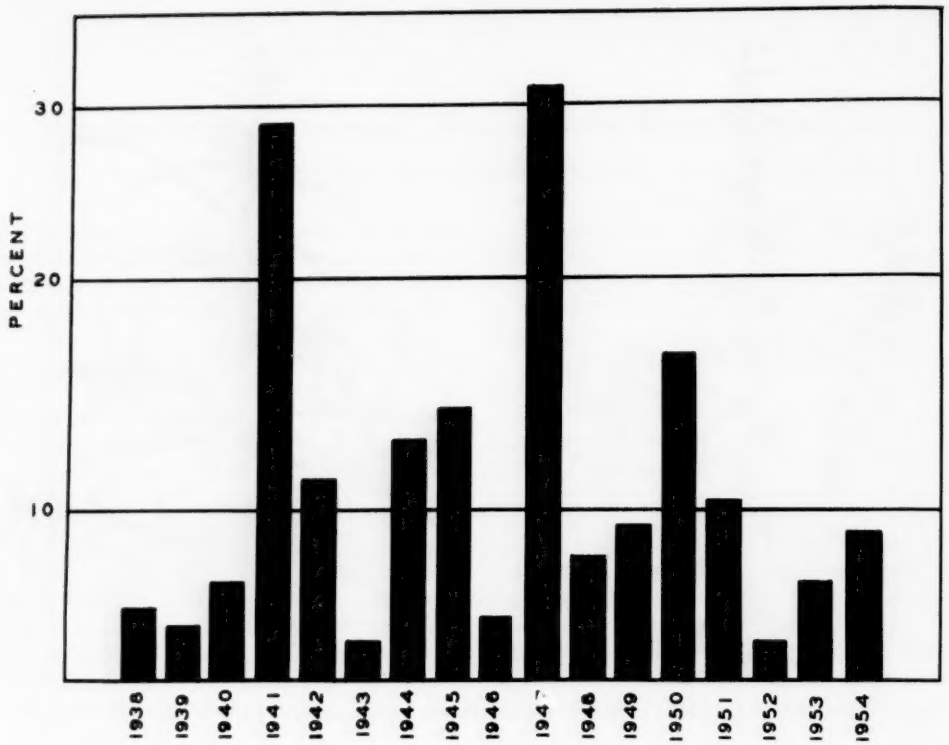

FIG. 3.—Percentage of beet leafhoppers carrying the curly-top virus from annual fall collections of Russian-thistle.

smotherweed were close in the Idaho-Nevada-Utah district, but in the Nyssa district the average on smotherweed was 20% lower than that on Russian-thistle. In the Idaho-Nevada-Utah district the leafhoppers were more abundant on smotherweed than on Russian-thistle in 1947, but the situation was just the reverse in 1950. There were high populations in both years. Similar reversals were recorded during years when the average pouplations were low. In the Nyssa district the differences between these two hosts ranged from 15% in 1945 to 73% in 1949, but the average difference for the 10-year period was not significant since Russian-thistle had the higher population for 7 years and smotherweed for 3 years. The physiological conditions of the plants should be studied to determine their relative suitability as hosts from year to year.

Soil conditions in large areas of the Nyssa district are favorable for smotherweed, and it is often an important source of high leafhopper populations. Over the 10-year period the area covered with Russian-thistle in this district ranged from 8 to 59 thousand acres (Table 3). The average acreage of smotherweed was about 20 per cent of that of Russian-thistle, and this plant produced about 15% as many leafhoppers. In 1947 smotherweed produced about 29% as many leafhoppers as Russian-thistle.

Douglass *et al.* (1944) indicated that the suitability of halogeton and Russian-thistle for the production of high populations of beet leafhoppers was similar. As shown in table 2, the average population was higher on Russian-thistle than on halogeton during each of the 8 years of this study, but the difference ranged from slight in 1943 and 1948 to nearly 14 times as many on Russian-thistle in 1950.

These studies confirm the statement of Fox (1945) that "In southcentral Idaho Russian-thistle is the most important and widely distributed summer host plant of the beet leafhopper." Halogeton has spread over several

Table 1.—Curly-top infection of beet leafhoppers reared on four host plants.[a]

HOST PLANT	NUMBER TESTED	PER CENT INFECTED
Smotherweed	1,387	0
Halogeton	523	15
Kochia	382	21
Russian-thistle	40	2

[a] Preliminary laboratory tests.

Table 2.—Number of beet leafhoppers per square foot on three host plants in the Idaho-Nevada-Utah district, 1943–50.

YEAR	HALOGETON	RUSSIAN-THISTLE	SMOTHERWEED
1943	4	5	—
1944	3	8	8
1945	1	4	2
1946	2	4	5
1947	5	33	40
1948	3	4	3
1949	3	13	7
1950	3	45	32
Average	3	14	14

Table 3.—Beet leafhopper populations on Russian-thistle and smotherweed in the Nyssa district.

	Russian-Thistle		Smotherweed	
Year	Acres	Leaf-hoppers per Square Foot	Acres	Leaf-hoppers per Square Foot
1942	—	10	—	17
1943	48,858	14	5,555	7
1944	39,853	11	7,546	13
1945	8,032	9	4,224	7
1946	10,131	13	4,902	5
1947	26,656	50	6,234	61
1948	21,267	7	4,013	4
1949	26,771	32	4,826	9
1950	59,008	31	8,027	20
1951	22,682	13	5,690	6
Average	29,251	19	5,668	15

thousand square miles in nine counties of southern Idaho, but it is not likely to produce as many leafhoppers per square foot as Russian-thistle. Kochia and smotherweed are good hosts of this insect, but their distribution has never equaled that of Russian-thistle in the leafhopper-breeding areas included in this study. Since kochia is a good reservoir of curly top and is abundant in eastern Colorado, western Kansas, and Nebraska, it may become an important host of this insect in the intermountain area, as it is being planted as a forage plant in Utah.

SUMMARY.—The suitability of four summer host plants —halogeton, kochia, Russian-thistle, and smotherweed— as reservoirs of the curly-top virus and for the reproduction of the beet leafhopper (*Circulifer tenellus* (Bak.)) was studied from 1938 to 1954 in the breeding areas of southcentral Idaho, eastern Oregon, northeastern Nevada and northwestern Utah.

Laboratory studies indicated that halogeton and kochia are much more suitable than Russian-thistle and smotherweed as reservoirs of the virus of curly top.

The field studies showed that Russian-thistle and smotherweed are about equal and much more suitable than halogeton for the reproduction of the beet leafhopper.

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Adult Buprestid Causes Crop Damage[1]

R. C. DOBSON and J. G. WATTS[2]

The adults of the buprestid, *Psiloptera drummondi* L. & S., have been observed to cause injury to various plants in New Mexico. This injury consists of clipping the terminals or fruit from the plants attacked. Damage of this type is very rarely attributed to adult buprestids. Cotton, pecans, bear grass (*Nolina microcarpa* S. Wats.), and honey locust (*Gleditsia triacanthos* L.) have been attacked in New Mexico and Texas in recent years.

The injury to cotton consists of partially girdling the terminals so that they break over and die. Injury to pecans is caused by clipping green nuts from the trees. The cut is always made at the point of juncture between the stem and the twig. Honey locust twigs are girdled in the same manner as cotton, whereas the fruiting stems of bear grass are clipped at the base of the seed heads. According to correspondence from G. B. Vogt (1949), "these beetles attack the branch tips, often chewing them off, of coyotillo, guajillo, etc."

According to Chamberlin (1926), *P. drummondi* has been taken in Kansas, Arizona, Texas, New Mexico, California, and Mexico. He lists the host plant as *Petalstesnon multiflorus.* This is probably *Petalostemum multiflorum* Nutt. as listed in Grey (1908). The adults have been collected at State College and Dona Ana, New Mexico, in 1953 and 1954, at Yselta, Texas, in 1949, and at Logan, New Mexico, in 1954.

Control measures were directed against this insect on a 10-acre cotton field at Dona Ana, New Mexico, in August, 1954. A 5% DDT dust, applied by air at 30 pounds per acre, gave good control. At the time of the application, 80 to 90% of the terminals had been clipped.

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SCIENTIFIC NOTES

Rohm & Haas FW-293 for Mite Control on Ornamentals[1]

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Rohm & Haas FW-293[2] gave excellent control of the cyclamen mite, *Steneotarsonemus pallidus* (Banks), the privet mite, *Brevipalpus inornatus* (Banks), and the two-spotted spider mite, *Tetranychus telarius* (L.), in tests conducted in 1955. These are the most important species of mites attacking floricultural crops in southern California. While the two-spotted spider mite is the most common and has the widest host range, the cyclamen mite has been the most difficult to control. Endrin appears to be the most effective material against the cyclamen mite (Morishita & Jefferson 1955), and has given excellent commercial control in California. Chlorobenzilate is effective against both the privet mite and the two-spotted spider mite, but of the other materials currently in use for the latter species, Aramite is only moderately effective against the privet mite and the organic phosphorus compounds are ineffective (Morishita 1954, Pritchard 1949).

The investigations reported in this paper were begun primarily for the control of the cyclamen mite. When promising results were obtained in laboratory tests, a series of experiments was arranged in which FW-293 was tested on a commercial scale against the cyclamen mite, the privet mite, and the two-spotted spider mite.

LABORATORY TESTS AGAINST THE CYCLAMEN MITE.—The procedure used was described by Morishita & Jefferson (1955). Materials used were an 18.5% FW-293 emulsion and a 17.5% endrin emulsion.[3] These were applied at the rate of 1 quart of the emulsion plus 4 ounces of Triton X-100[4] per 100 gallons. Three thorough spray applications approximately a week apart were made.

The first experiment was begun in April, 1955. Each material was applied to 30 heavily infested Saintpaulia plants with 30 plants left as checks. In an examination prior to the second application no live mites were found on the treated plants while the check plants were still heavily infested. Six weeks after the first application the plants treated with FW-293 and endrin were recovering with no evidence of any additional mite damage. At the end of 3 months, however, a few plants in the FW-293 treatment were beginning to show the first symptoms of cyclamen mite injury. During this period no change occurred in the check plants which made no new growth and produced no buds or flowers.

A second experiment, in which Saintpaulia, Cyclamen and Gloxinia plants were used, was begun in August. Results were similar to those obtained in the first experiment. By the end of September all of the treated plants had recovered and were making good growth, but during November a few Saintpaulia plants in the FW-293 treatment began to show evidence of mite damage.

COMMERCIAL TESTS.—High-volume sprays were applied with power equipment in all tests. Unless otherwise stated, the effectiveness of the treatments was checked 4 to 6 weeks after the last application. Percentage mortality counts were not made since the objective of the treatments was eradication. In the case of the cyclamen mite, the treatments were also judged on the basis of the recovery of the plants and the absence of mite injury to new growth. The tests, which are described in chronological order, were begun in July and continued into November.

Excellent control of the cyclamen mite and the privet mite was obtained in a greenhouse range specializing in potted plants. There was a general infestation of the privet mite throughout and light, scattered infestations of the cyclamen mite. Three sprays a week apart were applied by the grower, using 1 quart of the 18.5% FW-293 emulsion per 100 gallons.

Good control of the cyclamen mite was obtained on a large planting of ornamental strawberry used as a ground cover. This planting had been previously sprayed with Aramite and malathion without control and damage from the mites was severe. A commercial pest control operator applied three FW-293 sprays at 7- to 10-day intervals. A dosage of 1 quart of the 18.5% emulsion per 100 gallons was used in the first spray and 1½ pints per 100 gallons in the second and third sprays. The planting recovered following these sprays and no further evidence of mite injury was observed during the summer and fall.

A greenhouse of Schefflera plants infested with the cyclamen mite was sprayed on August 17, August 24 and September 9. The dosage used was 1 quart of the 18.5% FW-293 emulsion plus 4 ounces of Triton X-100 per 100 gallons. Excellent control was obtained and no further indication of cyclamen mite injury was observed during the fall.

In a test on greenhouse roses a single application of 1 pound of the 18.5% FW-293 wettable powder plus 2 ounces of Multifilm L[5] per 100 gallons was applied to a bench infested with the two-spotted spider mite. The mites in this range have shown resistance to current acaricides although the degree of resistance is not known. Examination a week after treatment indicated good control, although eradication was not obtained.

A light but general infestation of the two-spotted spider mite and the privet mite in a small nursery containing many tropical and subtropical plants was completely cleaned up with a single spray application in which 1 pound of the 18.5% FW-293 wettable powder plus 2 ounces of Multifilm L per 100 gallons was used.

A single, thorough application of 1 quart of the 18.5% FW-293 emulsion plus 4 ounces of Triton X-100 per 100 gallons was made to ivy, fibrous begonia and Gynura plants infested with the cyclamen mite. While normally control of the cyclamen mite is not obtained from a single spray, at the end of 6 weeks no live mites or evidence of mite injury to new growth was found.

In the last experiment, ivy heavily infested with the privet mite was sprayed with FW-293 using 1 quart of the 18.5% emulsion plus 4 ounces of Triton X-100 per 100 gallons. Examination a month later showed that excellent control had been obtained. The same result was obtained when the check area was sprayed with the dosage reduced to 1½ pints of the emulsion per 100 gallons.

CONCLUSIONS.—From the results of these experiments it would appear that Rohm & Haas FW-293 will have an important place in mite control programs on ornamentals. It compared favorably with endrin against the cyclamen mite although the laboratory tests indicated that more frequent applications may be necessary. This is offset, however, by its much lower animal toxicity. In addition, no other single material currently available will effectively control the cyclamen mite, the privet mite and the two-spotted spider mite. This is of importance to

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[1] Accepted for publication March 28, 1956.
[2] Also called Kelthane. Formulations used were a xylene base emulsifiable concentrate containing 18.5% FW-293 (ca. 1.5 pounds actual FW-293 per gallon) and a wettable powder containing 18.5% FW-293, furnished by Rohm & Haas.
[3] Containing 1.6 pounds of endrin per gallon, furnished by Shell Chemical Corp.
[4] Alkylated aryl poly-ether alcohols, Rohm and Haas Co.
[5] Colloidal spreader and deposit builder containing petroleum sulphonates, petroleum oil and free and combined fatty acids, Colloidal Products Corp.

the grower since mixed infestations of these species often occur on many floricultural crops.

Plant tolerance to FW-293 appears to be excellent as a dosage of 1 quart of the 18.5% emulsion per 100 gallons was applied to a wide variety of plants without any significant injury.

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Dusting for Horn Fly Control on Beef Herds[1]

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Lindquist & Hoffman (1954) reported good control of horn flies, *Siphona irritans* (L.), for 3 weeks on dairy cattle with hand applications of dry 50% methoxychlor wettable powder. They suggested that the method might be useful to owners of less than 50 cattle. Many Wyoming dairymen have taken to the method, and most prefer dusting to spraying the animals.

Tests in 1955 near Wheatland, Wyoming, indicated that "dusting" with dry wettable powders might also be useful for horn fly control for owners of large beef herds, especially those who do not have power sprayers or who have not had successful control from rubbing devices.

A hand-operated rotary duster[2] was used in making the applications. A duster of the type used costs about $25 to $49, depending on weight, gear ratio, and hopper capacity. A flexible hose was attached between the fan case and discharge tube, and the Y attachment with double nozzles and deflectors was removed to facilitate aiming the dust. Removal of the double nozzles also reduced the weight, thereby greatly lessening the strain on the operator.

In some of the tests, cattle were crowded into a small corral or squeeze pen as is done for spraying, and dust was applied to their backs as the operator perched on the railings. For such applications one or two extra lengths of tubing would be desirable. A better method was to hold cattle in a large corral and dust them while walking among them (Fig. 1). This has the advantage that cattle can be dusted in almost any type of enclosure that will hold them, and if desirable, dusting can be done in distant corrals inaccessible or difficult to get to with spraying equipment and water. In addition, the job can be handled rather well by one man working alone.

The time required for dusting is comparable with that for spraying. For herds that were squeezed into small pens in groups, treatment was made at the rate of about three head per minute including the time used in running the groups into and out of the dusting pen. In other words, a herd of 100 cattle run through the dusting pen in five to seven groups could be treated in about 30 minutes for the entire operation. Less time was required when the cattle were held in a large corral and dusted as the operator walked among them.

DeFoliart (1954) found that 2 quarts per animal of 0.5% DDT spray resulted in an average of 26.5 days' control of horn flies on cattle in tests in the same area in which the dusting was done. Two quarts of 0.5% DDT spray deposits approximately 9 grams of DDT on the animal. In the dusting tests, 19 to 26 grams of 50% DDT wettable were discharged per animal, or approximately 9 to 13 grams of actual toxicant per animal. No difference in control was apparent in the range of 9 to 13 grams. The dusting treatments with 50% DDT wettable powder averaged 23.5 days' control (25 or less flies per animal.) In three tests 1.0% dieldrin dust was applied and averaged 15 days' control at rate of 12 to 19 grams per animal. In one test, 25% dieldrin wettable powder at 17 grams per animal also gave 15 days' control.

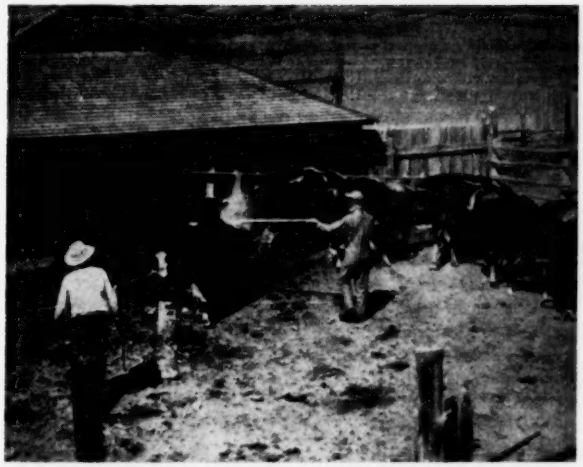

FIG. 1.—Dusting range cattle for horn fly control.

The dusting method appears to be another tool for horn fly control not only for the small operator, but also for owners of large herds. Ranchers who cooperated in these tests were enthusiastic about the method. It appears to be as fast and economical as spraying and about as effective, and requires a relatively small initial investment for equipment.

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[1] Published with approval of the Director, Wyoming Agricultural Experiment Station, as Journal Paper No. 68. Accepted for publication December 5, 1955.

[2] Supplied by H. D. Hudson Manufacturing Company, Sprayer and Duster Division, Chicago, Ill.

A Method for Labeling the Lone Star Tick with a Radioactive Indicator (P^{32})[1]

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In the development of a program for the study of the overwintering habits of the lone star tick, *Amblyomma americanum* (L.), it was realized that a need existed for a suitable method of marking ticks for identification in the field. Early attempts at marking involved the use of paint, but such a method had obvious limitations. Individual handling prohibited the use of large experimental tick populations and in addition it was believed that the paints may have interfered with respiratory and

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[4] The authors express their appreciation to the following who contributed to the development of this project: Mr. F. M. Philips, Fourth Army Area Medical Laboratory; Cpl. E. C. Hartwig, Radioisotope Unit, Brooke Army Hospital; and Mr. George M. Padilla, Dept. of Zoology University, of California at Los Angeles.

sensory organs. A review of the available literature indicates that ticks have not been labeled with a radioactive substance prior to this time (Jenkins 1954). Since other investigators have successfully utilized radioactive tracers with certain insects in field studies, this mechanical method of labeling was explored.

In addition to the development of a mechanical technique for labeling ticks, studies on the effectiveness of a wetting agent as an aid in increasing uptake and retaining radioactivity on the ticks was investigated. Recent advances in insect labeling techniques have shown that a small amount of wetting agent added to a radioactive solution would improve the labeling effects (Babers *et al.* 1954, Roth & Hoffman 1953).

All the ticks used in these preliminary experiments were collected from Camp Bullis, Texas, where a heavy infestation is present. In addition to this supply of ticks, a colony was established during the winter of 1955 from ticks sent to this laboratory by the Rocky Mountain Laboratory, Hamilton, Montana. This group was reared in the laboratory after the culture methods of Kohls (1936).

In the early stages of this project, plans were made to feed ticks on small mammals such as guinea pigs or rats which had previously been given a dose of radioactive P^{32}. This technique had been originally reported by Yates *et al.* (1951) for marking mosquitos. It seemed that certain problems would be encountered such as time elapsing during the feeding of ticks, disposal of contaminated wastes, such as excretory products of the hosts, and the additional expense for purchase and maintenance of laboratory animals. These conditions could be eliminated if the ticks were tagged by direct application of the radioactive material. Babers *et al.* (1954) and Roth & Hoffman (1953) had previously demonstrated that certain insects could be marked efficiently by dipping in a solution of radioactive salts. A procedure incorporating this principle was evolved and is discussed.

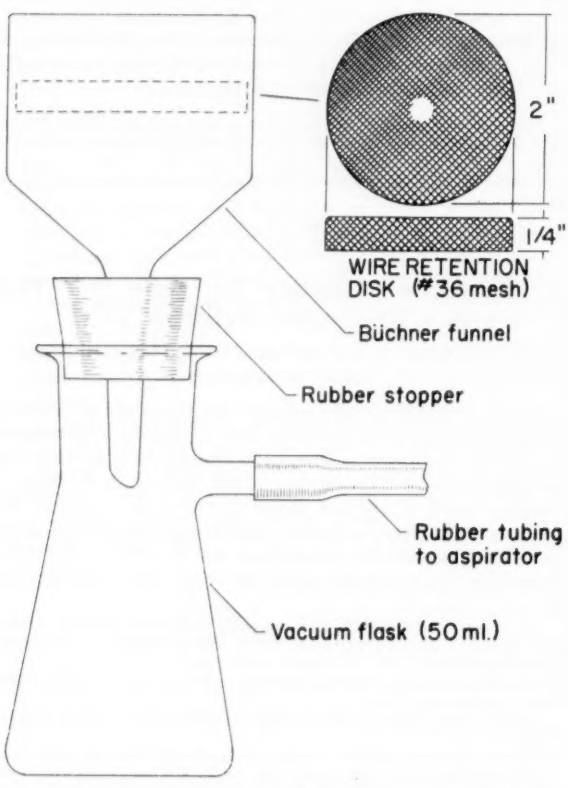

FIG. 1.—Büchner funnel apparatus used for washing ticks with radioactive P^{32}.

METHODS AND RESULTS.—Ticks were made radioactive by placing them in a Coors-type Büchner funnel, 2 inches in diameter, attached to a 50-ml. vacuum flask (Fig. 1). In order to confine the ticks in the funnel, a disk $\frac{1}{4}$ inch high and $1\frac{7}{8}$ inches in diameter, cut from 36-mesh brass wire, was inserted into the apparatus. A $\frac{1}{4}$-inch-diameter hole was made in the center of the disk through which the ticks were placed into the funnel. As many as 200 ticks were held in this apparatus at one time. The solution containing radioactive phosphorus was poured into the funnel, allowed to stand for 1 minute, and removed by vaucum. This procedure was carried out three times using the same solution.

The solution of radioactive phosphorus in the form of NaH_2PO_4 (sodium dihydrogen phosphate) had a specific activity of 10

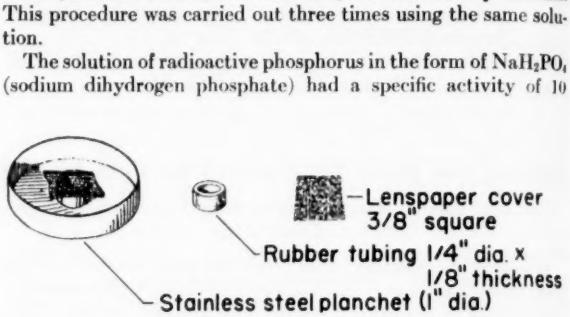

FIG. 2.—Planchet device used for holding ticks under the end window counting tube.

microcuries per milliliter. A total of 10 milliliters of solution was used for each group of ticks labeled. In some instances the wetting agents, Triton X-100 and tergitol number 7 (sodium heptadecyl sulfate) were used at a concentration of 0.1 per cent. After removal of the radioactive solution the ticks were transferred to clean petri dishes and stored in a desiccating jar containing a saturated solution of ammonium sulfate. This solution provided a constant humidity of 80 ± 1 per cent, which has been proven necessary for the successful maintenance of tick colonies (Lancaster 1955). The desiccator was kept in a constant ambient temperature of $23 \pm 2°C$.

Labeled ticks were measured for uptake and retention of radioactive P^{32} with a mica end-window Geiger-Muller tube, window thickness 1.8 mg/cm^2, attached to an autoscaler (Tracer Lab. SC-51). Counting rates were obtained with a preset of 6,000 counts. Ticks were placed individually in stainless steel planchets which were centered $\frac{1}{2}$ inch below the G-M tube window. In order to immobilize ticks in the planchets while counting, a piece of $\frac{1}{4}$-inch-diameter rubber tubing, $\frac{1}{8}$ inch in length, was glued in the center of each planchet. Over this rubber ring a piece of lens paper $\frac{3}{8}$ inch square was attached (Fig. 2). After placing the tick in the retaining ring the edges of the lens paper were glued to the rubber ring, thus restricting the tick's movement. All counts were made in this manner, with the dorsal side of the tick facing the counting tube window.

Approximately 1300 ticks were successfully labeled for various studies. The mean counting rates in counts per minute for lots of about 25 ticks reported in table I show that in all cases sufficient amounts of activity are present to provide positive identification. The distribution of counting rates within the majority of the lots was positively skewed and statistically non-normal;

Table 1.—Summary of counting rates (min.$^{-1}$) for ticks treated with P^{32}.[a]

	MALE	FEMALE
No wetting agent	278	397
Tx-100	159	293
Ter. #7	210	451

[a] Values represent mean counting rates fourteen days after treatment. Data presented only to indicate magnitude of counting rates.

therefore, judgments of the effects of treatments should not be based on the mean values reported. The data as reported are of interest only to demonstrate the magnitude of counting rates.

The toxic effects of P^{32} and wetting agents were determined by treating four groups of ticks as folllows: (1) control—not treated; (2) 10 ml P^{32}; (3) 10 ml P^{32} and tergitol number 7; and (4) 10 ml P^{32} and Triton X-100. Fourteen days after treatment the ticks were examined and the number of survivors noted. The results were summarized and subjected to a chi-square analysis (Tables 2 and 3).

Male ticks treated with P^{32} and wetting agents in various combinations did not exhibit any significant difference from male ticks receiving no treatment. Comparisons between wetting agent and no wetting agent in the presence of P^{32}, and the difference between the two wetting agents were both non-significant. The results of the survival study of the female ticks, when compared as above, were found to show significant differences as between female ticks treated, and as between wetting agents and no wetting agents in the presence of P^{32}. There was, however, no significant difference in survival rates of female ticks when the comparison was between the two wetting agents used.

Table 2.—Numbers of ticks surviving after 14 days' treatment with P^{32} and wetting agents.

	Control	P^{32}	P^{32} and Tergitol #7	P^{32} and Triton X-100
Male				
Number	9	37	33	25
Total	13	51	51	50
Per cent	69.2	72.5	64.7	50.0
Female				
Number	47	37	24	25
Total	52	52	48	46
Per cent	90.4	71.2	50.0	54.3

Table 3.—Chi-square analysis of survival results shown in table 2.

	df	Male	Female
Control vs. treated	1	0.23	17.23[a]
P^{32} and wetting agent vs. P^{32} and no wetting agent	1	3.33	5.50[b]
Tergitol #7 vs. Triton X-100	1	2.34	0.20

[a] Significant at 1% level.
[b] Significant at 5% level.

SUMMARY.—Approximately 1300 ticks, *Amblyomma americanum*, were labeled with radioactive phosphorus by means of an external labeling technique. This technique involved the use of a Büchner funnel and vacuum flask in which the ticks were held during submersion in a radioactive solution.

Labeled ticks were checked for presence of radioactivity with an autoscaler equipped with a G-M tube. The ticks were held in place under this tube by means of a stainless steel planchet and rubber retaining ring with a lens paper cover.

Addition of wetting agent did not increase uptake or retention of P^{32} but did substantially reduce survival of female ticks when used in concentrations of 0.1 per cent. Since there was no observable advantage and there was a definite reduction in survival of treated female ticks, wetting agents are not recommended for the external labeling technique.

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A Comparison of Back Rubber Formulations for Controlling Horn and Stable Flies in Iowa[1]

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The control of fly populations on beef and dairy cattle is very important to cattlemen all over the United States. It is generally believed that stable and horn flies reduce weight gains as much as ½ pound per day and milk production by 10 to 20 per cent on those cattle heavily attacked by these flies. The cheapest and most practical method of controlling the horn fly, *Siphona irritans* (L), was first described by Rogoff & Moxon (1952). Widespread use of this method of horn fly control has been made by Iowa cattle producers. This method of insecticidal application did not appear to be very effective against *Stomoxys calcitrans* (L), the stable fly. In Iowa stable fly populations on cattle sometimes reach an average of several hundred flies per animal during July and August. It would be desirable to adapt the cheapness and ease of construction of the cable-type back rubber to the control of stable flies as well as horn flies and to this end the field tests described below were carried out.

EXPERIMENTAL PROCEDURE.—In early June, 13 herds of cattle were selected as to location, type of cattle and type of pasture in which the animals were running. Ten of these were "treated" herds and the other three were left untreated as "check" animals. Three of the treated and one of the check herds were dairy cattle primarily of holstein breed. The remainder were hereford beef stock.

In each of the pastures containing herds to be treated, a cable-type back rubber was installed at a location where the animals appeared to loaf when not feeding. These back rubbers were made as uniformly as possible according to the diagram in figure 1. In two instances, however, the units were attached to trees, where the animals loafed, instead of to posts.

On June 23, after pretreatment-counts of the flies on the animals were taken, the burlap wrappings were treated with the insecticides to be tested. Each of the test insecticides was used on two herds. In every case 5 quarts of the particular insecticide were required to soak the burlap wrappings to saturation. The insecticides tested consisted of the following concentrate formulations:

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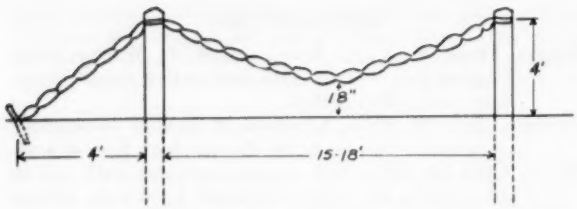

FIG. 1.—Cable type back rubber. Made by setting two posts in the ground and fastening four strands of twisted barbed wire wrapped with burlap to the posts.

I. 40% butoxypolypropylene glycol and 20% DDT in methylated naphthalenes; II. 20% DDT in methylated naphthalenes and petroleum distillate; III. 40% butoxypolypropylene glycol and 16% methoxychlor in methylated naphthalenes; IV. 16% methoxychlor in methylated naphthalenes; V. 50% butoxypolypropylene glycol, 5% methoxychlor, 40.6% methylated naphthalenes, and 4.4% alkyl aryl poly ether alcohols.

Concentrates I and II were diluted with No. 2 fuel oil so that they contained 4% DDT. Formulation I therefore contained 8% butoxypolypropylene glycol. Concentrates III and IV were diluted before use on the back rubbers so that they each contained 4% methoxychlor and formulation III contained 10% butoxypolypropylene glycol. Concentrate V was used on the back rubbers undiluted.

Fly counts were made on one side of each of 10 animals in each herd nearly every day during the test period. Field glasses were used to determine fly species. Only stable and horn flies were counted, ignoring the few house flies which were found on the animals in the pasture. All herds were examined each day fly counts were made. Since considerable time was required to complete the count on each herd, the rotation of counts was never quite the same to prevent time of day and temperature from playing too great a part in the final results.

In an attempt to determine the hour of the day in which there were the greatest number of flies on the animals, hourly counts were made on 10 animals in 3 herds on 2 different days. The period of greatest activity appeared to be the late afternoon hours. The counts made at 4:00 P.M. and at 5:00 P.M. showed the largest numbers of both species under study (Table 1). The numbers prior to that time seemed to be relatively uniform. Since counts on insecticide-treated cattle were made prior to 4:00 P.M., time of day should not be an important factor in affecting the results. Of interest were the 9:00 P.M. counts when the largest number of horn flies were present and no stable flies were on the animals.

RESULTS.—All formulations tested on the cable-type back rubbers for the control of biting flies on cattle proved very efficient against the horn fly. Percentages of control ranged from 94.2 to 99.9. (Table 2). The differences between the fly counts on the treated and the untreated herds were highly significant.

Table 1.—Fly counts made on 10 animals in three untreated herds at intervals on 2 different days. Ames, Iowa. 1955.

TIME	TOTAL NUMBER OF	
	Stable Flies	Horn Flies
8:00 A.M.	238	948
10:00 A.M.	308	611
11:00 A.M.	323	801
1:00 P.M.	375	699
2:00 P.M.	364	968
4:00 P.M.	511	1300
5:00 P.M.	541	1235
9:00 P.M.	0	1420

Table 2.—Average number of horn flies per animal per day on 10 herds using cable-type back rubbers treated with five insecticide formulations. Ames, Iowa. 1955.

FORMULATIONS	HERD NO.	JUNE 25–29	JUNE 29–JULY 5	JULY 5–12	JULY 12–19	JULY 19–29	5-WEEK AVERAGE	PER CENT CONTROL
I	1	3.9	9.3	26.8	24.0	16.4	19.6	94.2
	2	1.6	0.9	1.8	1.8	0.1	1.2	99.6
II	3	16.2	20.7	4.9	1.7	0.9	7.1	97.9
	4	1.7	3.0	1.9	1.3	1.3	1.9	99.4
III	5	3.6	0.0	0.7	0.8	0.2	0.5	99.9
	6	0.2	0.6	0.6	0.3	0.0	0.4	99.9
IV	7	—	0.4	4.2	—[a]	—	2.0	99.4
	8	0.1	0.9	0.2	1.4	2.1	1.2	99.6
V	9	0.7	1.3	17.1	7.2	4.0	8.0	97.6
	10	0.1	0.6	2.7	1.5	3.9	2.2	99.3
Untreated	11	277	308	676	705	161	512	0.0
	12	41	59	87	5.1[b]	2.3[b]	51	0.0
	13	182	159	110	207	58	150	0.0

[a] Changes of herd pastures forced dropping this herd from the experiment.
[b] Horn fly numbers dropped due to DDT corn borer spray in adjoining corn field so counts were not figured in averages.

However, the differences between treatments were not significant. Excellent control of the horn flies was obtained for at least 5 weeks. The counts were terminated at the end of that period because horn fly numbers had dropped considerably even on untreated animals due to high temperatures and drouth conditions.

None of the materials tested gave stable fly control. In table 3 it would appear that treated herds had fewer stable flies than untreated herds. However, there was no significant difference between numbers of stable flies due to high variations within herds.

The materials used in this way caused no toxic effects except formulation II. Herd no. 3, utilizing a back rubber soaked with 5% DDT in No. 2 fuel oil, had two new born calves severely burned around the head, neck and shoulders during the first week after saturation of the burlap. When the calves were kept away from the back rubber the skin condition cleared up and the hair grew back.

The skin irritation was probably caused by the petroleum distillate in the original DDT formulation rather than the No. 2 fuel oil used to dilute all concentrates. No ill effects were noted on young calves in four other herds utilizing other formulations containing no petroleum distillate in the concentrate. Formulation IV, which contained the highest concentration of methylated naphthalenes, caused no skin irritation on young calves in herd No. 8.

SUMMARY.—During a 5-week period in the summer of 1955, fly counts were made on 13 herds of cattle to determine the effectiveness of five insecticide formulations in the control of horn and stable flies. The formulations were diluted with No. 2 fuel oil and applied to the burlap wrappings of cable-type back rubbers in the pastures of 10 of the 13 observation herds.

Table 3.—Average number of stable flies per animal per day on 10 herds using cable-type rubbers treated with five insecticide formulations. Ames, Iowa. 1955.

FORMULATIONS	HERD NO.	JUNE 25–29	JUNE 29–JULY 5	JULY 5–12	JULY 12–19	JULY 19–29	5-WEEK AVERAGES
I	1	8.8	8.1	8.9	18.4	53.2	14.1
	2	9.8	7.0	13.7	22.4	75.7	15.9
II	3	5.4	7.9	8.9	10.9	13.8	8.0
	4	4.9	8.2	9.0	17.9	43.4	10.5
III	5	2.6	9.3	18.6	21.3	31.3	17.6
	6	4.7	10.4	14.1	19.7	62.8	15.7
IV	7	—	5.4	15.0	—[a]	—	9.9
	8	5.8	8.5	15.2	19.9	71.1	17.7
V	9	7.6	8.8	15.6	20.9	82.1	13.4
	10	2.4	4.2	9.1	11.9	19.1	9.4
Untreated	11	5.1	12.2	19.8	23.4	38.2	15.9
	12	8.3	7.9	22.5	19.6	126.4	27.2
	13	8.7	9.9	31.1	32.7	82.5	35.2

[a] Changes of herd pastures forced dropping this herd from the experiment.

All formulations gave almost perfect control of horn fly populations on the cattle for the entire 5-week observation period. None of the formulations controlled the stable fly populations to any significant degree.

The diluted materials as applied to the back rubbers contained the following insecticides:

I. 8% butoxypolypropylene glycol and 4% DDT; II. 4% DDT; III. 10% butoxypolypropylene glycol and 4% methoxychlor; IV. 4% methoxychlor; V. 50% butoxypolypropylene glycol and 5% methoxychlor

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Biologies of the Peach Tree Borer and Lesser Peach Tree Borer in East Texas[1]

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Research by Driggers & Smith (1944) using summer sprays to control the peach tree borer, *Sanninoidea exitiosa* (Say), initiated studies on the effect of trunk sprays during the period of adult emergence and oviposition. Research on the life history of the borer in the peach producing regions of the United States established the dates of adult emergence upon which the timing of control applications depended. Martin (1953) obtained satisfactory control with trunk sprays, but erratic results were obtained the following year due to annual variations in the time of emergence of the adults. This variation led to the initiation of life history studies.

To determine the development of the immature stages throughout the season, larval and pupal populations were sampled biweekly from January, 1954 through January, 1955. Samples of about 20 larvae and pupae were obtained from the bases of the trunks of several trees. Adult emergence was determined during 1955 by weekly counts of empty pupal skins around the bases of 20 marked trees. The cases were destroyed after each count.

The head capsules of each of the larvae collected were measured. The frequencies of occurrence of the measurements were plotted to ascertain the number of larval instars. Considerable fluctuation was observed and the distribution of frequencies did not disclose a pattern from which the number of instars could be discerned readily.

Each probable combination of instar ranges was compared by statistical analysis to expected values obtained from a ratio using Dyar's Rule. The data indicated that either five, six or seven stadia were required for larval development. However, a comparison of means of observed ranges with values obtained by a ratio of geometric progression according to Dyar's Rule disclosed that seven instars were extremely unlikely.

Correlation with computed ratios was obtained with means of both five and six instar ranges. If five instars were presumed to exist, examination of the data indicated that the last instar head capsule measurements encompassed a disproportionately large range. Although a small percentage of larvae may complete development in five instars, the majority was considered to pass through six instars before pupating.

The means and ranges for the six instar combination selected are presented in table 1. The larvae were classified according to their respective instars. The percentage of larvae in each instar and of pupae was computed and plotted for each collection date. Records of emergence of the moths, obtained as described above, are included in the graph presented in figure 1. As illustrated in figure 1, the peach tree borer passes through one generation annually in East Texas. The adults emerge from late in May to October. A noticeable decline occurs in early August followed by a peak of emergence in September. No attempt was made to determine whether two generations occur in Texas as they do in a negligible number of cases in Georgia (Snapp & Thomson 1943).

Table 1.—Means and ranges in mm. of head capsule measurements of the larval instars of the peach tree borer.

	RANGE	MEAN
First instar	35–62	51
Second instar	75–101	90
Third instar	102–139	125
Fourth instar	140–180	163
Fifth instar	184–259	225
Sixth instar	263–380	297

To determine the life cycle of the lesser peach tree borer, *Synanthedon pictipes* (G. & R.), samples were obtained from damaged areas of the trees in the same manner as previously discussed for the peach tree borer. Head capsule measurements were made and instars determined from the ranges previously established by King (1917). The percentage of each instar on each collection date was calculated and these data together with adult emergence records are presented in figure 2.

A high percentage of lesser peach tree borers completes two generations annually in East Texas. The remainder, after completing one generation, remains in the sixth instar during the fall and winter, emerging as adults early in the spring. The peak of adult emergence occurs for the first generation in late April and early May, and for the second generation in September.

SUMMARY.—The peach tree borer completes one generation annually in East Texas. The larvae apparently require six instars for their development, although some may pass through only five. The peak of adult emergence occurs in September.

One complete generation and a partial second generation of the lesser peach tree borer occur annually in East Texas. Larvae overwinter in all instars except the first. First generation adult emergence is greatest in late April and early May. The second generation emerges in September.

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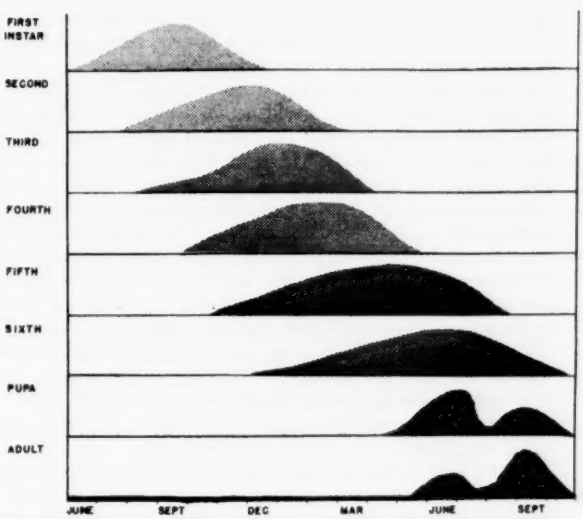

FIG. 1.—Life cycle of the peach tree borer in East Texas.

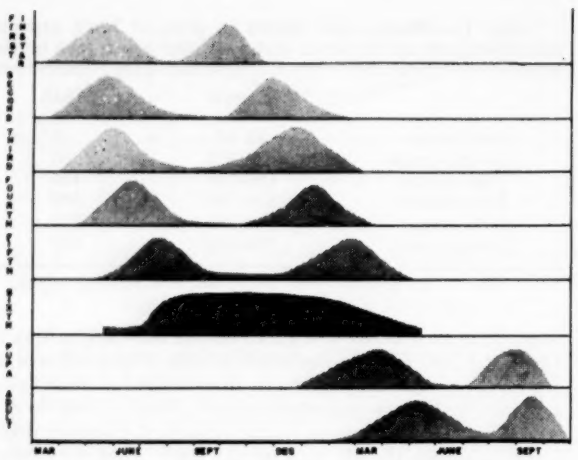

FIG. 2.—Life cycle of the lesser peach tree borer in East Texas.

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Thrips Damage to Apple[1]

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During the harvest season of 1952 in the Anderson Valley of California, a considerable number of mature Golden and Red Delicious apples were affected by the presence of deep pits in the side of the fruit. Since the majority of apples from this area are sold as fresh fruit, this condition caused the apples to be classed as culls. Other apple varieties grown in the area were not affected, the damage being restricted to the two varieties mentioned. The nature of the damage suggested insects, perhaps a feeding puncture which occurred while the fruit was very small.

In 1953, a survey was made of the Anderson Valley to see if the cause of the dimpling could be discovered. Box elder bugs were found abundantly near the orchards but no large numbers were found within the orchard. Both this insect and lygus bugs were suspected, but the survey showed that lygus could be eliminated since they were not present in the early season. Thrips were another suspect, as they were found in the blossoms during the blooming period. An exploratory treatment with DDT as a petal fall spray was made in an orchard, but the percentage of damaged fruit was the same in the sprayed trees as unsprayed trees when fruit damage counts were made. The 1953 survey gave the following information: by observation it was learned that the damage occurs early in the season, lygus bugs or other late appearing insects were not involved, petal fall codling moth treatments were of little value, and the causal agent was either a thrips or the box elder bug.

In the 1954 season, two orchards which had reported damage the previous season were surveyed for insects which could be responsible for the damage. In one orchard, a rather high population of box elder bugs were present and were found both on and beneath the trees. Near the other orchard, a source of box elder bugs was located, but none were found in this orchard. In both orchards, thrips were present in the blossoms and were identified as the madrone thrips, *Thrips madroni* Moulton. Both insects were investigated as possible causal agents of the fruit pitting.

Box elder bugs were observed feeding on the young apples, but all of their feeding was restricted to the calyx cups and none were observed feeding on the sides of the apples where the pitting occurs. Box elder bugs were confined in plastic bags which were placed over twigs containing young apples, and periodic examinations did not reveal any punctures in the sides of the fruit. In addition, a portion of the orchard which had a high population of box elder bugs was treated with heptachlor in order to destroy the insects. Subsequent fruit examinations showed 5.5% injury present in both the treated and untreated areas. The above observations led to the conclusion that box elder bugs were not responsible for the fruit pitting.

Observations on the madrone thrips, however, showed that the thrips were probably responsible for the damage. Adult and nymphal thrips were found in the blossoms throughout the blooming period, and the first evidence of damage to the young fruit occurred during the late bloom period. In the early stages of fruit growth, the damage appeared as a raised scabbed spot surrounded by a circular depressed area. Microscopic examination of these spots indicated that these were thrips egg punctures rather than feeding areas. Two types of damage were noted, one the so-called pansy spot which is typical of thrips egg puncture on young apples, and the other as described above. The depressed areas varied from distinct pits to slight depressions surrounded by a pansy spot. Young apples showing various types of damage were tagged to determine their final appearance when the fruit was mature. In most cases, young apples with pronounced depressions were deeply pitted at harvest. Those with pansy spots or only a slight depressed area out-grew the damage and were free from symptoms at harvest. The pitting of young fruit was evident only on Golden and Red Delicious apples. Pansy spots were present and, on occasion, numerous on other apple varieties such as Rome, Jonathan and Gravenstein, but no pits were present, and by harvest, all evidence of thrips egg punctures had disappeared. It seemed evident therefore, that *Thrips madroni* was responsible for the damage to Golden and Red Delicious apples, and the pitting was a result of egg punctures in the young fruit. Evidently these two varieties of apple are more sensitive to thrips egg punctures than other varieties.

During the 1954 season, counts were made on a grower's plot in which he sprayed one block at early petal fall on April 19

[1] Accepted for publication January 27, 1955.

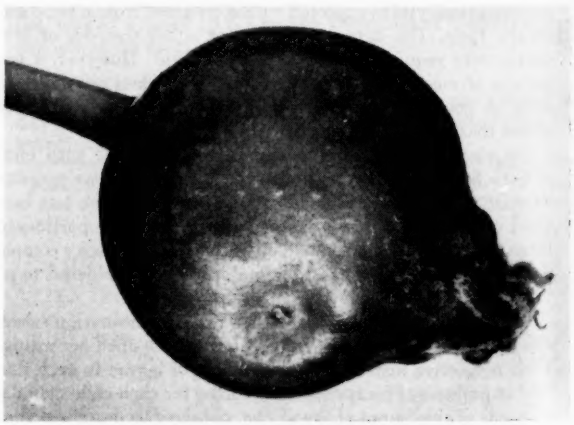

FIG. 1.—Thrips egg puncture on young fruit.

Summary of thrips tests on apple. Boonville, California, 1955.

Date of Application[a]	Per Cent Thrips Damage on Young Fruit May 16	Per Cent Fruit Pitted at Harvest Sept. 27
Gowan Orchard		
Pre-bloom—April 4	21.3	6.1
Petal fall—May 2	36.0	11.0
2 weeks after petal fall—May 16	35.4	11.8
Untreated check	36.3	13.8
Williams Orchard		
Pre-bloom—April 4	26.0	2.2
Petal fall—May 2	40.0	12.5
2 weeks after petal fall—May 16	43.4	10.6
Untreated check	50.0	13.0
Cook Orchard		
Pre-bloom—April 4 and petal fall—May 2	16.6	1.0
Petal fall—May 2	34.6	6.2
2 weeks after petal fall—May 16	36.6	5.6

[a] Two pounds of 50% DDT wettable powder per 100 gallons applied to all eated plots.

and the other at the normal timing for the first codling moth spray on April 26. On May 19, the fruit sprayed April 19 showed 5% thrips injury, while the fruit treated April 26 had 13% injury. At harvest, the same blocks showed 1% and 4.6% pitted fruit respectively. It was evident from these observations that an early treatment was necessary in order to provide control.

It was noted that the percentage pitted fruit at harvest was less than recorded on the young fruit. This reduction was due to two factors, (a) some of the fruit may grow out of the early damage, and (b) during thinning operations, many of the pitted fruits are removed. Growers who are aware of the problem instruct the thinners to remove fruit with obvious pits present.

The madrone thrips, the casual agent of fruit pitting in this area, is a native species and has a rather wide host range on many of the native flowering trees and shrubs of California.

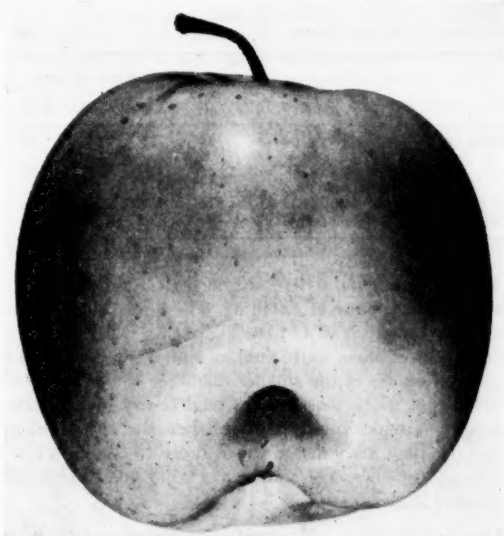

FIG. 2.—Mature apple with pit resulting from early thrips egg puncture.

Madrone, manzanita, willow, ceanothus, toyon, and others have been recorded as hosts. The complete biology of the madrone thrips and its relation to apples has not been determined.

In the 1955 season, a series of plots was established in order to determine the correct timing of spray applications for the control of madrone thrips. DDT was selected as the insecticide, and plots were established in three orchards in the Anderson valley. It was decided to make applications at the following periods: pre-bloom or pink stage, full bloom, petal fall, and 2 weeks after petal fall. In two orchards (Gowan and Williams) the applications were made with conventional ground equipment, and in the Cook orchard, applications were made by the grower with blower-sprayer equipment.

Observations were made on the thrips during the period from pink bud stage in April through the petal fall period in late May. Adult thrips were found in the unopened blossoms during the pink bud stage and throughout the blooming period. Egg punctures were not observed on the young fruit until the late bloom period, when the flower petals tend to fold back and contact the surface of the developing fruit. Evidently, the thrips puncture the young fruit at that time, when they can find protection beneath the petals. Egg punctures increased in number on the young fruit from the late bloom period until petal fall, and it was possible to dissect out the eggs under a binocular microscope. After the petal fall period, no thrips, adult or nymphs, could be found on the trees, and most of the eggs present on the fruit had hatched. It was evident therefore, that most of the fruit damage occurred between the period of late bloom and petal fall.

The sprayed plots, as originally established, provided for applications during the pink bud, full bloom, petal fall and 2 weeks after petal fall stages. Unfortunately, continued rains throughout the blooming period made it impossible to apply sprays during the full bloom. The evaluation of this timing period was therefore lost. After the last application, counts were made of the thrips punctures present on the immature fruit, and at harvest, counts were taken of the number of mature fruits which were pitted. The results are summarized in table 1 and indicate that the only treatment which reduced the damage was the pre-bloom spray. As was shown by the observations on thrips behavior, the damage had occurred by the petal fall stage. It is probable that an application during full bloom would be the ideal time to obtain control, but a treatment at this time would no doubt result in the destruction of pollinating insects. In the 1955 plots, there was a considerable population of thrips in untreated trees which could have reinfested the pre-bloom treated plots during the blooming period. It is therefore possible that if an entire orchard were treated during the pre-bloom period, commercial control might be obtained.

SUMMARY.—Fruit pitting on Golden and Red Delicious varieties of apple in the Anderson Valley of California was determined to be caused by the egg puncture of the madrone thrips, *Thrips madroni* Moulton. Adult thrips are present in the blossoms as early as the pink bud stage, and the eggs are laid in the young fruit during the period from late-bloom to petal fall. Tests to determine the best timing of DDT applications showed that a pre-bloom spray gave fair control, but that treatments during the petal fall stage and later were not effective.

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The Effect of Different Host Species on the Oviposition and Survival of the Introduced Pine Sawfly[1]

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The introduced pine sawfly, *Diprion similis* (Htg.) was discovered first in the United States in Connecticut (Britton 1915). At the present time it is found throughout the northeastern states as far west as Minnesota, and in eastern Canada. According to Craighead (1950) the five-needled pines are the preferred host species, but there are records also of larval feeding on some of the softer two-needled pines. Dr. C. E. Atwood (personal communication) stated that he found *D. similis* only on two-needled pines in Canada prior to 1953, but since then larvae have been found on white pine, *Pinus strobus* L., at Toronto. In another communication, Dr. Blair M. McGugan says that the larvae of *D. similis* were collected most commonly on Scotch pine, *Pinus sylvestris* L. in southern Ontario during the period of 1938 to 1951, inclusive. Collections from white pine and other species were reported much less frequently. The records provided by Mr. Raizenne of the Canadian Division of Forest Biology show the following breakdown for 119 collections of larvae of this sawfly: 107 on *Pinus sylvestris* L., 5 on *P. strobus* L., 2 on *P. resinosa* Ait., 2 on *P. banksiana* Lamb., and 3 on *P. mugho* Turra.

Larvae of *D. simliis* were found on white pine planted on the campus of the University of Minnesota in 1939, Hodson & Christensen (1942). Four years later a 25-year-old white pine plantation located at Lake Vadnais near St. Paul, Minnesota was heavily defoliated by this sawfly. Plantings of jack, red and Scotch pine growing nearby or adjacent to the white pine were infested lightly or not at all. In 1942, ornamental mugho pines were damaged severely in the St. Paul area, but only light infestations have been found infrequently since that time, Hodson & Christensen (1944). More recently Shenefelt & Benjamin (1955) show a photograph of a roadside planting of white and red pine and spruce, in which the white pine was defoliated completely and the red pine was not harmed.

The differential host preference observed in Minnesota and reported elsewhere led the authors to seek an explanation. It was postulated that the apparent preference for and greater damage to white pine might be explained by one or more of the following:

(1) A preference for white pine for oviposition,
(2) a greater fecundity when oviposition takes place on white pine,
(3) a better survival of eggs laid on white pine, or
(4) a better survival of larvae feeding on white pine.

METHODS.—Cocoons were collected in a white pine plantation in the early spring and were stored at 0° C. until needed. The adults emerged and mated within 2 weeks after being transferred to room temperature. Eggs were obtained by confining adults in cages with cut branches or by releasing them in sleeve cages placed over the branches of the host trees. Whenever cut branches were used to observe oviposition or larval feeding the cut ends were kept in water which was changed daily. Tests were made with five species of pine: white, red, jack, Scotch and mugho.

HOST SELECTION FOR OVIPOSITION.—Experiments were set up in which the adults had a choice of hosts for oviposition. Five branches, approximately equal in size, taken from the five species of pines, were placed together in a random order in a bottle containing water. These branches were enclosed in a cage with sawfly adults. Five pairs were used in each of 5 replicates, and 8 females and 7 males were used in 4 other replicates. The number of eggs deposited in the needles of each branch was counted after the death of all the females. The results are given in table 1.

Table 1.—Choice of hosts for oviposition by adults of *Diprion similis*.

Species of Pine	Average No. of Eggs		Total No. of Eggs	Relative Values for Choice of Host
	Replicates 1–5	Replicates 6–9	Replicates 1–9	
White	118.6	64.8	852	100
Scotch	21.2	10.0	146	17
Red	8.4	41.0	206	24
Jack	26.2	29.8	250	29
Mugho	6.2	4.5	49	6
L.S.D. at 5% level	44.8	41.4		

In replicates 1–5 the choice of white pine for oviposition by the adults was highly significant. In replicates 6–9 white pine also was preferred over the other species but the differences between white, and red and jack pine were not significant. Generally speaking, white pine ranked first in the choice for oviposition and mugho pine was last; while Scotch, red and jack pine held variable positions between these two extremes.

OVIPOSITION RATE AND EGG MORTALITY.—Pairs of sawflies and single females were confined in separate cages on branches of the different pines growing in a plantation. The actual and potential fecundity of the individual females was determined by counting the number of eggs that they deposited in needles, and by dissecting them after death and counting their unexpended eggs. The average potential fecundity of 57 females was 70 eggs, with a range of from 26 to 105. It was noticed that the number of eggs laid by the females was not influenced by the presence or absence of males, as reported by Zappe (1917).

The experiments showed that, on the average, the sawflies laid more eggs on white, Scotch and jack pine than on red and mugho pine (Table 2). However, the differences were not significant. This lack of significance may be due in part to the large variation in potential fecundity among the females. In other words, the number of eggs deposited on the different hosts and the percentage of the potential fecundity of the females which they represent were of the same order of magnitude; while the potential fecundity itself varied independently of the host trees.

Table 2.—The fecundity and egg mortality of *Diprion similis* on different hosts.

		Species of Pine				
		White	Scotch	Red	Jack	Mugho
Fecundity	Ave. No. eggs per female	44	36	19	32	9
	Per cent of eggs laid per female	61	51	26	45	14
Egg mortality	No. of eggs examined	475	530	223	338	109
	Per cent mortality	45	26	44	23	16

Egg mortality data were obtained by examining the eggs in the field at the time of hatching. The lowest egg mortality occurred on mugho pine and the highest on white pine (Table 2). In this respect alone white pine was inferior to the other species, possibly because of the smaller diameter of the needles. It was noticed that white pine needles tend to dry rapidly after being injured by oviposition and that when the eggs swell prior to hatching, they are exposed much more to the air when laid in white pine needles. The similar mortality on red pine cannot be explained in this way.

[1] Paper No. 3463 Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul. Accepted for publication December 5, 1955.
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[3] Professor, University of Minnesota.

LARVAL SURVIVAL ON DIFFERENT HOSTS.—The mortality of larval stages was determined by rearing them on cut branches of each of the pines in the laboratory. Twenty or thirty newly hatched larvae were reared on each of several branches. When the branches were changed during the rearing study the number of living and dead larvae was counted and their instars recorded. The mortality data are given in table 3.

Table 3.—The mortality of larvae of *Diprion similis* on different hosts.

SPECIES OF PINE	NO. OF LARVAE	PER CENT MORTALITY	PERCENTAGES OF DIFFERENT INSTARS AMONG DEAD LARVAE				
			1st	2nd	3rd	4th	5th
White	121	15	72	22	0	0	6
Scotch	99	25	24	20	16	4	36
Red	106	22	57	35	4	0	4
Jack	110	28	58	22	6	3	11
Mugho	136	80	89	5	0	1	5

The highest mortality, 80%, occurred on mugho pine, and the lowest, 15%, on white pine. The mortalities on the other three species fell in between and were all about the same. Most of the larvae died during the first instar with the exception of those on Scotch pine. On this species the mortality was distributed more evenly among the instars.

SUMMARY.—Host infestation records in eastern United States and in Minnesota have led to the conclusion that some populations of the sawfly, *Diprion similis* Htg., are likely to attack white pine more heavily than species of two-needled pines. It was postulated that the heavier infestation of white pine might be due to one or more of the following: a preference for white pine for oviposition, a greater fecundity when oviposition takes place on white pine, or a better survival of eggs and/or larvae on white pine. Experiments were performed to test this postulate in which five species of pine were compared: white, Scotch, red, jack, and mugho.

It was found that white pine was the most suitable host for *D. similis* with respect to host preference for oviposition, that fecundity was greatest when eggs were deposited on white pine, and that larval survival was highest when they fed on white pine. White pine was somewhat inferior to three of the four species of two-needled pines tested with respect to egg survival in the needles, and mugho pine was superior to any of the other species only in this respect. These results provide a biological basis for explaining the fact that white pine may show complete defoliation by this sawfly, while the other species considered may be infested only lightly even though they may be growing near or among white pine trees.

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Granulated Insecticides Against Greenhead (*Tabanus*) Larvae in the Salt Marsh[1]

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The salt marsh greenhead, *Tabanus nigrovittatus* Macq., is an important pest of man in resort areas and of animals along the Atlantic coast of New Jersey. Until the advent of DDT no satisfactory control measures had been developed. By the use of DDT, Gerry (1949) was able to control greenhead adults in resort areas by proper timing and application of the insecticide by aircraft to marsh areas adjacent to the resorts. In New Jersey, however, it has been impossible to use this method because the amounts of DDT needed will have adverse effects on other life as reported by Springer & Webster (1951).

While other insecticides might be tried against adult tabanids, larval control appears to be more satisfactory since it prevents the emergence of adult flies, treatment need be applied only to the marsh, and control measures probably could be spread over a longer period. Since granulated insecticides seemed to have advantages over other types of formulations, all tests were made with such formulations prepared on ground tobacco stems.[3]

Previous work (Hansens 1952) showed that the marshes at Leeds Point and the Brigantine Wildlife Refuge harbored large populations of greenheads with immature stages abundant in the marsh; consequently, these locations were selected for study. Areas of up to 40 acres which were surrounded by large acreages of similar salt marsh were treated. The entire area was *Spartina alterniflora* marsh and surveys had shown it to be rather uniformly infested with *Tabanus* larvae, averaging 1 to 30 larvae to the square yard with the heaviest infestation in the wettest areas.

MEASUREMENT OF RESULTS.—In order to determine results of treatments, each spring and late summer counts of larvae were made on representative areas of 2 to 5 square yards. Vegetation was removed from the area by mowing the grass and raking off the cut vegetation. The cleared area was then sprinkled with lindane or pyrethrum larvicide using 2 quarts of dilute larvicide per square yard. The lindane larvicide consisted of ½ pint of 20% lindane emulsion in 5 gallons of water. The pyrethrum larvicide was prepared by diluting New Jersey mosquito larvicide 1 part to 9 parts of water (either fresh or brakish). These larvicides gave equally good results though the lindane stimulated larvae to come to the surface sooner. Each area was watched carefully for 15 minutes after treatment and at intervals for an additional 45 minutes, during which time all greenhead larvae were collected. Very few larvae came to the surface more than an hour after larvicide treatment.

It was necessary to select the proper time for observations, i.e., when tides were low and when the surface of the marsh was dry enough to permit larvicide to penetrate the sod. In the time available as many observations as possible were made on each plot—50 square yards per plot if possible.

TESTS IN 1951.—Tests were begun in August, 1951, on two plots of 25 acres each at Leeds Point. Areas adjacent to each end of the plot were used as untreated checks. For this initial test granulated formulations containing 5% dieldrin and 1% gamma isomer of BHC on tobacco stem were selected for application by airplane at rates of 10 pounds of formulation per acre. Dust particles ranged from 30- to 60-screen mesh in size. Actual applications were made under excellent flying conditions on August 24.

After treatment of representative areas in each plot with larvicide the number of larvae coming to the surface were counted. Results (Table 1) show that 1% BHC gave partial kill initially

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[3] All materials supplied by Tobacco By-Products Corp., a Division of Virginia-Carolina Chemical Corp., Richmond, Va.

Table 1.—*Tabanus* larvae taken from plots treated with granulated insecticides in 1951.

Treatment	Date Examined	Square Yards Examined	Larvae per Square Yard
BHC, 1%	August 1951	28	0.2
	June 1952	75	1.9
	August 1952	25	4.4
	June 1953	40	5.9
Dieldrin, 5%	August 1951	26	0.04
	June 1952	45	0
	August 1952	25	0
	June 1953	60	0
	September 1953	50	0.8
Check	August 1951	8	3.8
	June 1952	50	0.9
	August 1952	25	1.0
	June 1953	60	1.7
	September 1953	50	3.6

but since it did not have residual activity the 1952 brood of greenhead larvae developed quite normally. On the other hand, dieldrin gave excellent results, nearly wiping out larvae in 1951, completely wiping out larvae in 1952 and reducing the size of the 1953 brood. Most other animal life, however, was adversely affected by dieldrin. Unfortunately, the larval population in some of the untreated check areas was found to be low.

Tests in 1952.—In 1952, applications of granulated insecticides were made in the same fashion as in 1951 on a series of four 40-acre plots on the Brigantine Wildlife Refuge. Since the 1% concentration gave mediocre results 2% BHC was used and because of adverse affects of the 5% dieldrin application on marsh fauna, 2% diledrin was used. In addition, 10% DDT and 2% aldrin were added to the test series. The insecticides, formulated on ground tobacco stems, were applied by airplane at the rate of 10 pounds per acre on August 7. As shown in table 2, the dieldrin formulation gave the best results with complete eradication of the 1952 population as well as the overwintering larvae. A year after treatment only a few larvae were taken on this plot. Aldrin gave next best results while DDT and BHC were unsatisfactory in residual effects. All materials gave good kills for at least a month after insecticides were applied.

Table 2.—*Tabanus* larvae taken from plots treated with granulated insecticide in 1952.

Treatment	Date Examined	Square Yards Examined	Larvae per Square Yard
BHC, 2%	August 1952	25	0.2
	June 1953	30	0.5
	September 1953	50	1.4
Aldrin, 2%	August 1952	25	0
	June 1953	60	0.2
	September 1953	50	2.1
DDT, 10%	August 1952	25	0
	June 1953	30	0.9
	September 1953	50	3.1
	June 1954	50	2.4
	June 1955	100	8.2
Dieldrin, 2%	August 1952	25	0
	June 1953	60	0
	September 1953	50	0.2
	June 1954	50	1.8
	June 1955	100	7.5
Check	August 1952	25	1.3
	June 1953	60	1.7
	September 1953	50	3.6
	June 1954	25	4.2

Table 3.—*Tabanus* larvae surviving in salt marsh treated by hand duster with granulated dieldrin.

Per Cent Toxicant	Applied	Larvae per Square Yard: September 1953	June 1954	June 1955
1	July 9, 1953	0.04	0.3	4.2
2	July 9, 1953	0.02	0.4	2.2
1	July 31, 1953	0.32	0.2	3.0
2	July 31, 1953	0.13	0.3	5.3
1 (15- to 30-mesh)	August 12, 1954	—	—	0.7
1 30- to 60-mesh)	August 12, 1954	—	—	0.5
2 (30- to 60-mesh)	August 12, 1954	—	—	0.2
Untreated		1.7[a]	4.2	5.8
Square Yards Examined		50	50	30

[a] 10 square yards examined.

Tests in 1953 and 1954.—In 1953 and 1954, small plots of ¼ acre were treated with granulated formulations of 1% and 2% dieldrin on ground tobacco stems. These plots were treated by walking back and forth across the plots at 10-foot intervals with a hand operated rotary duster and then repeating the treatment by walking at right angles. The duster was set to deliver 10 pounds of dust to the acre by trial applications on marsh areas. In practice uniform treatments were made by placing the exact amount of dust needed into the duster and applying all dust on the test area.

In 1953 a total of eight plots was dusted, half with 1% dieldrin on ground tobacco stems and half with 2% dieldrin on the same carrier. Half of the plots were treated on July 9 and the other half on July 31. Each treatment was replicated once.

Observations on larval survival in each plot and in untreated areas were made on 25 square yards in September 1953 and June 1954 and on 15 square yards in June 1955. On August 12, 1954 six plots were treated with similar formulations. Two ¼-acre plots were treated with 1% dieldrin on tobacco stems which would pass 15- to 30- mesh screen; 2 with 1% dieldrin formulations which would likewise pass 30- to 60-mesh screen. Larval survey was planned for September 1954 but inclement weather and high tides prevented this. Larval survival was checked in May and June 1955 by examination of 15 square yards on each plot.

Table 3 shows first of all that hand-application from the ground did not give as good results as air application for some larvae survived on most of the plots. On all plots, however, the dieldrin granulated formulations markedly reduced the populations of greenhead larvae without apparent serious damage to other life. Though the differences are small, application early in the season seemed to give better results than application later in the year, and relatively high concentrations gave slightly better results than the low ones.

Summary.—Over a 4-year period, granulated insecticide formulations have been applied to salt marsh areas for control of greenhead (*Tabanus nigrovittatus*) larvae. Dieldrin at 1, 2, and 5% formulated on ground tobacco stems markedly reduced greenhead larval populations. Five per cent dieldrin applied from the air eliminated larvae from the treated marsh for 2 years but did serious damage to other animal life. Dieldrin at 1 or 2% did much less damage and reduced greenhead populations for at least a year after application. DDT, aldrin, and BHC similarly formulated gave good initial kills but were ineffective as residuals.

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Control of Insects Affecting Vetch Seed Production[1]

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An experiment was conducted near Terrell, Texas, Kaufman County, in 1955 to determine the effect of certain insecticides on insects attacking vetch. Davis & Swenson (1953) obtained excellent control of the pea aphid with parathion, malathion, Metacide and Systox. DDT and some other insecticides were somewhat less effective. Since it has been demonstrated that honey bees are valuable for pollinating vetch (Weaver 1954), insecticides with low toxocity to these pollinators were included in order to hold the loss of honey bees to a minimum. Weaver (1953) listed the following insecticides in order of increasing toxicity to honey bees: toxaphene, DDT, chlordane, BHC, 3-5-40, aldrin, dieldrin, parathion and calcium arsenate. The vetch was grown primarily for seed production, but it also was used for late-winter and early-spring grazing.

Insecticides were applied primarily for the control of the pea aphid, *Macrosiphum pisi* (Harris); variegated cutworm, *Peridroma margaritosa* (Haw.); black cutworm, *Agrotis ypsilon* (Rott.); and armyworm, *Pseudaletia unipuncta* (Haw.). Other lepidopterous insects occurring in small numbers were the alfalfa looper, *Autographa californica* (Speyer); green cloverworm, *Plathypena scabra* (F.); clay-backed cutworm, *Agrotis gladiaria* Morrison; webworm, *Loxostege* spp.; and corn earworm, *Heliothis zea* (Boddie). The green cloverworm occurred in fairly large numbers but only slight damage was evident. Populations of thrips, *Frankliniella tritici* (Fitch), *F. occidentalis* (Pergande) and *F. exigua* (Hood), were high at the time the vetch was in full bloom. No treatment was made for the control of thrips.

The plots in this experiment were arranged in randomized blocks with each treatment replicated four times. Each plot was 0.1 acre in size. The insecticide sprays used are given in tables 1 and 2. One application of each insecticide was made on April 5 with a self-propelled spray machine, equipped with hollow-cone nozzles, at the rate of 6 gallons per acre using a pressure of 60 p.s.i. The spray machine was operated at approximately 4 miles per hour.

RESULTS.—Results of the tests conducted for the control of pea aphids are shown in table 1. The vetch was harvested on June 1. The spray containing a mixture of toxaphene and DDT in the ratio of 2 to 1 at the rate of 3 pounds of active ingredient per acre controlled the aphids for 3 weeks. Parathion sprays controlled aphids for 2 weeks. Malathion was fairly effective for three weeks after application. Populations of beneficial insects, especially lady beetles and lacewing flies, were higher in the check plots than in the treated plots 4 weeks after treatment. This apparently accounts for the low population of 4.6 aphids per sweep in the check plots, as compared with 47, 126 and 53 per sweep 30 days after treatment in the plots sprayed with malathion, parathion and toxaphene-DDT, respectively. Although infestations increased in all three treated plots 4 weeks later, these populations subsided at the end of the fifth week. A combination of beneficial insects and increased temperature probably accounted for the reduction of aphid populations.

Table 2.—Results of test for the control of armyworms and cutworms on vetch.

Treatment	Pounds of Active Ingredient per Acre	Worms per Square Foot Before Treatment	Per Cent Reduction from Check After			
		Apr. 5	2 Days	9 Days	15 Days	21 Days
Malathion	0.5	4.5	35.9	46.5	33.6	10.2
Parathion	0.25	5.1	48.7	85.3	82.2	85.5
Toxaphene-DDT (2:1)	3.0	3.4	79.5	99.0	100.0	100.0
Check	None	2.8				

The results obtained with malathion, parathion and toxaphene-DDT on cutworms and armyworms are given in table 2. The variegated cutworm was the predominant cutworm species and the true armyworm was the most prevalent of the armyworm group. The initial infestation averaged about four armyworms and cutworms per square foot of soil surface examined. Highest population was 40 per square foot in untreated plots approximately 3 weeks after the experiment was initiated.

Of the three treatments, the toxaphene-DDT spray gave the best control for armyworms and cutworms. Almost 100% control was maintained throughout the period necessary for producing vetch seeds. Fair control was obtained with parathion spray, but malathion was very poor. Apparently only one generation of armyworms and cutworms occurred during the experiment since only an occasional worm was found 1 month after treatment on April 5.

Vetch seed yields and net gains in pounds per acre are given in table 3.

SUMMARY.—Three insecticide sprays, malathion, parathion and toxaphene-DDT, were applied to vetch near Terrell, Texas, in 1955 for the control of insects. The chief injurious insects were the pea aphid and certain species of armyworms and cutworms.

Each of the three insecticides controlled pea aphids but toxaphene-DDT gave the best control of aphids, armyworms and cutworms.

An increase of 272 pounds of vetch seed per acre was obtained

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Table 1.—Results of test for control of the pea aphid on vetch.

Treatment	Pounds of Active Ingredient per Acre	Aphids per Sweep Before Treatment		Aphids per Sweep and Per Cent Control							
				Apr. 7		Apr. 14		Apr. 20		Apr. 26	
		Mar. 31	Apr. 5	Average Number	Per Cent	Average Number	Per Cent	Average Number	Per Cent	Average Number	Per Cent
Malathion	0.5	67	319	1.75	99.8	2.0	99.8	33.8	98.5	174.9	71.5
Parathion	0.25	45	154	0.5	99.9	1.5	99.8	26.9	97.6	192.9	34.7
Toxaphene-DDT	3.0	55	315	1.75	99.7	0.75	99.9	8.1	99.6	33.1	94.5
Check	None	55	233	508.9		785.4		1680.4		447.3	

Table 3.—Vetch seed yields.

Treatment	Pounds of Active Ingredient per Acre	Pounds per Acre	
		Seed Yield	Net Gain
Malathion	0.5	264	112
Parathion	0.25	336	184
Toxaphene-DDT (2:1)	3.0	424	272
Check	None	152	
L.S.D. at 5% level		139.5	

by the use of one application of toxaphene-DDT spray at the rate of 3 pounds of active ingredient per acre. Malathion- and parathion-treated plots showed yield gains but they were not as great as the yields from plots treated with the toxaphene-DDT mixture.

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Control of *Tetranychus hicoriae* McG. on Pecans[1]

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Damaging populations of the mite, *Tetranychus hicoriae* McG., often develop in pecans in the late summer and fall. Heavy infestations frequently result in defoliation before the nuts mature. Experiments prior to 1953 in several locations indicated that injurious populations of mites may develop after a single application of certain insecticides and fungicides. Pierce (1953) noted that outbreaks of mites follow the application of DDT for the control of the pecan nut casebearer, *Acrobasis caryae* Grote, a major insect pest of pecans.

Insecticides effective in controlling the pecan nut casebearer were applied to determine their effects on the subsequent development of mite populations. Records were kept of the numbers of mites that occurred during the summer following a single application of these materials in early May for the control of the pecan nut casebearer. Data from an experiment in 1955 (table 1)

Table 1.—Mite populations following one application of insecticides for control of pecan nut casebearer. 1955.

Treatment Applied May 6	Pounds or Pints per 100 Gallons of Water	Average Number of Mites per 10 Leaflets August 15
50% DDT, W.P.	2	37
	1	13
25% malathion, W.P.	2	11
	1	26
40% toxaphene, W.P.	5	8
	3.5	13
18.5% endrin, E.C.	1.25	8
50% DDT+sulfur, W.P.	2	1
Check		1

Table 2.—Mite populations following four applications of fungicides for pecan scab control.

Treatment	Rate per 100 Gallons of Water	Average Number of Mites per 10 Leaflets	
		Sept. 7	Sept. 11
Bordeaux mixture	6-2-100	26	35
Captan 50W	2 lb.	16	57
Emmi 50-CS-46[a]	2 oz.	25	35
Zineb[b]	2 lb.	1	11
Puratized Agricultural Spray[c]	1 qt.	45	112
Check		26	35

[a] Chlorinated organic mercury.
[b] Zineb—the proprietary form, Dithane Z-78 was used.
[c] Phenyl mercui trithanolammonium lactate.

illustrate that increased mite populations followed one spray application of each of the materials tested, except DDT plus 6 pounds of sulfur per 100 gallons of water. Apparently, early season populations of mites are controlled sufficiently with sulfur to prevent the development of damaging infestations later in the season.

As stated above, fungicides applied for the control of pecan scab disease caused by *Cladosporium effusum* also increase the incidence of mites. A study was made in 1953 using five fungicides to determine their relative inhibiting effects on the development of mite populations. Four spray applications were made of each material. All trees were sprayed with DDT to increase the incidence of mites. Mite counts were made 30 and 34 days after the last application. The results of this test, which are presented in table 2, indicate that zineb, applied at the rate of 2 pounds per 100 gallons of water, suppressed the development of mite populations. Further tests for mite control comparing zineb and Bordeaux mixture, the two commonly recommended fungicides on pecans, demonstrated that mite populations in trees sprayed with Bordeaux mixture were four times as great as those in trees sprayed with zineb.

In 1954 and 1955, three applications of zineb alone and in combination with DDT were compared with a single application of DDT plus sulfur. The results of these tests are presented in table 3. Zineb suppressed the build-up of mite populations to levels below those which developed in the check trees. The addition of sulfur to the early application of DDT for casebearer control effectively suppressed mite populations.

Zineb was compared with malathion and sulfur in another test to determine whether it was as effective as the latter materials in controlling established severe mite infestations. The results (table 4) indicate that a single application of zineb reduced such established infestations. However, it was more effective in

[1] Technical contribution No. 2348, Texas Agricultural Experiment Station, College Station. Accepted for publication February 10, 1956.
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Table 3.—Treatments, dates of application, and mite populations on pecans.

Treatment	Pounds per 100 Gallons of Water	1954 Mites per 40 Leaflets		1955 Mites per 10 Leaflets		
		June 29	July 9	Aug. 15	Aug. 23	Sept. 16
Zineb+50% DDT, W.P.	2+3	4	1	6	7	2
50% DDT	3	24	207	87	66	24
Zineb	2	2	1	2	3	2
50% DDT, W.P. +sulfur	3+6	—	—	16	9	10
Check		12	15	1	21	11

Table 4.—Comparative effectiveness of insecticides and a fungicide against pecan mites. Treatment applied August 19, 1955.

Treatment	Pounds per 100 Gallons of Water	Mites per 10 Leaflets		
		Aug. 23	Aug. 31	Sept. 16
25% malathion, W.P.	2	10	16	28
Sulfur (325 mesh)	2	4	0	0
Zineb	2	3	9	18
Check		20	5	100+

inhibiting mite population development when applied regularly in a disease control schedule.

SUMMARY.—The application of certain insecticides and fungicides resulted in the increase of mite populations on pecan trees. The addition of 6 pounds of sulfur per 100 gallons of water to DDT applied for control of pecan nut casebearer prevented the development of severe infestations of mites. The fungicide, zineb, applied at the rate of 2 pounds per 100 gallons of water in a regular pecan scab control schedule, also inhibited the development of damaging infestations of mites.

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Oversummering Volunteer Wheat in the Epidemiology of Wheat Streak-Mosaic[1]

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Studies have been made in Kansas to determine oversummering hosts of the wheat curl mite (*Aceria tulipae* (K)) and their importance in the epidemiology of wheat streak-mosaic. Painter & Schesser (1954) have reported western wheatgrass (*Agropyron smithii* (Rybd.)) to be a host of the wheat curl mite in Kansas. Painter *et al.* (1954) state: "They pass the summer between wheat crops on volunteer wheat and various grasses, especially western wheatgrass." Field observations on the mite and its oversummering hosts in Nebraska have been made by Staples & Allington (1956). Greenhouse studies of a number of wild and cultivated grasses as hosts for the mite have been reported by Connin (1956) and Slykhuis (1955).

The observations reported here were started in the spring of 1953 in a six-county area of north-central Kansas where the 1952–3 wheat crop was reported to have been diseased with streak-mosaic (Fellows & Sill 1955), and continued over the western two-thirds of the State. From 10 to 30 wheat plants were examined in fields taken at random at intervals of 5 to 10 miles. The wheat curl mite[2] was abundant over much of the area in which the disease was reported. Mites were either scarce or not present over the remainder of the area where observations were made.

After the wheat was harvested, wild grasses and weeds along the margins and in the stubble of the fields were examined microscopically for this mite. Adults, nymphs, and eggs were found on western wheatgrass in most of the western two-thirds of the State. In isolated places adult mites were found on Canada wildrye (*Elymus canadensis* L.), green foxtail (*Setaria viridis* (L.)), and smooth crabgrass (*Digitaria ischaemum* (Schreb.)). The mite was not found on 21 other species of grasses and weeds examined.

In July a survey was begun to locate the larger areas of volunteer wheat in Kansas, in the belief that these plants might provide the best host material for both vector and virus. Three such areas were found in the north-central, western, and central parts of the State. A smaller area containing scattered patches was found in the northeastern portion. Microscope examinations of wheat plants in these areas showed wheat curl mites to be most abundant on the early volunteer wheat. The presence of the mite on this wheat was often evidenced by rolled and trapped leaves. Volunteer wheat plants diseased with wheat streak-mosaic were prevalent in the north-central area, and were present in all the areas.

Late in September fall-seeded wheat began to emerge, and examinations were made in those fields. Wheat curl mites were found in the same areas where they had been present on volunteer wheat during the summer. Periodic examinations in some of these fields indicated that the mites were carried into the wheat by the wind from nearby volunteer wheat. In those areas where early volunteer wheat had not occurred during the summer, mites were absent or scarce on the seeded wheat plants.

Although wheat curl mites were found easily on western wheatgrass during the summer, they were never abundant. Under greenhouse conditions Connin (1956) rated western wheatgrass as a poor to fair host, and Slykhuis (1955) was unable to infest this grass with the mite in the greenhouse. Western wheatgrass is also immune to the wheat streak-mosaic virus (Sill & Connin 1954). The examination of fall-seeded wheat demonstrated that mites were absent or scarce in fields adjacent to western wheatgrass infested with wheat curl mites, unless early volunteer wheat containing mites had also been present during the summer. Therefore, it appears that western wheatgrass has little influence on the epidemiology of wheat streak-mosaic.

In the fall of 1953 plant pathologists of the Kansas Agricultural Experiment Station made a survey of seeded wheat to determine the presence of streak-mosaic. The areas in which the disease was reported (Sill *et al.* 1955) agreed closely with those in which early volunteer wheat and mites had been present during the summer.

These observations indicate that volunteer wheat, which emerges before or shortly after harvest of the seeded wheat, is of major importance in the epidemiology of wheat streak-mosaic. This volunteer wheat is susceptible to both vector and virus, and when present early enough, provides suitable host material for both.

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[1] Accepted for publication February 13, 1956. Contribution No. 654, Department of Entomology, Kansas Agricultural Experiment Station, Manhattan. Part of a cooperative project between the Entomology Research Branch and the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, and the Kansas Agricultural Experiment Station.

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Toxicity of Diazinon Vapors to Horn Flies[1]

WM. J. GOODWIN[2]

The horn fly, *Siphona irritans* (L.), is easily and effectively controlled with several chlorinated hydrocarbon insecticides and easily repelled with several of the more common repellents. Lindquist (1954) stated that a small amount of a 50% methoxychlor wettable powder dusted on the animal's back will give control of horn flies for a period of 3 weeks or longer. The author has made similar observations in South Carolina. DeFoilart (1954) working in Wyoming tested several chlorinated hydrocarbon insecticides and found most of them highly effective against this species. Goodwin *et al.* (1952) found that pyrethrins plus piperonyl butoxide and butoxy polypropylene glycol were highly effective in reducing the horn fly population on diary cattle in New York. A review of the literature has indicated the lack of information on the toxicity of the organic phosphate insecticides to this species.

Several herds of dairy cattle were selected for use in a biting fly repellent project. The milking barns were sprayed with experimental materials for house fly control. Observations made on these animals at weekly intervals indicated there was an extremely low horn fly population, considering that the animals had not been treated with any material for horn fly control. Two dairymen reported seeing the horn flies drop from the animals when housed on the day the barns were sprayed for house fly control. The two barns in this experiment had been treated with 0.5% suspension of Diazinon wettable powder at the rate of 1 gallon per 250 square feet. A close examination of the barn floors after treatment revealed a considerable number of dead horn flies. Dairy animals were checked for 10 days following this application of Diazinon, and the horn fly population did not reach 25 flies per animal, whereas, animals located on adjoining farms were averaging 200 or more flies.

The characteristics of this species have been observed by many workers. The fly remains on the host almost constantly, leaving only when disturbed or to deposit eggs. They do not leave the animals and rest on surfaces within the barn. Therefore, if Diazinon was toxic to the horn fly it would appear to be a result of the fumigating action of the vapors. Hansen (1955) working independently and at the same time this study was being conducted reported findings similar to those described in this paper.

The vapor pressure of Diazinon is 0.00014 mm. Hg at 20 degrees C. This pressure is approximately eight times that of parathion at the same temperature. The temperatures of the barns during this period were from 20 to 35 degrees C.

These observations were sufficient to warrant laboratory and field studies to determine if the Diazinon vapors were toxic to this species, and to determine the length of time this material remained effective as fumigant after being applied to the barn walls.

LABORATORY TESTS.—A series of laboratory tests were designed to test the contact and vapor action of Diazinon to horn flies. Small cages 12 by 10 by 8 inches constructed of 16-mesh screen wire were employed. A small electric hand gun was used to apply the Diazinon in all tests. The treated cages were held at a constant room temperature of 75 degrees F. and the check cages were held in a separate room at the same constant temperature. Horn flies were collected from dairy heifers by sweeping with an insect net and 200 were placed in each cage.

Three methods were used to determine the contact and vapor toxicity of Diazinon to horn flies as described below:

Test 1: This was the check with flies in an untreated cage. Flies lived for at least 8 hours off the host.

Test 2: The entire surface of the screened cage was sprayed with 0.5% Diazinon at the rate of 48.6 mg. per square foot.

Test 3: Two pine panels 10 by 4 by 0.5 inches were sprayed with 0.5% Diazinon at the rate of 18.5 mg. per square foot. These panels were placed in a small screen sleeve cage which in turn was placed in the fly cage. The horn flies could not come in contact with the treated surfaces.

Test 4: The interior of a pine box 15 by 12 by 15 inches was sprayed with 0.5% Diazinon at the rate of 45.0 mg. per square foot. The cage containing the flies was placed in the box, but the flies could not come in contact with the treated surfaces.

Test 2 was designed to determine the contact and vapor toxicity of Diazinon. Tests 3 and 4 were methods of determining the toxicity of Diazinon vapors to the horn fly.

Horn flies collected from dairy heifers were placed in the cages immediately after treatment and at intervals of 1, 4, 6, 13, and 21 days after the initial treatment. The cage, panels, and wooden box were not retreated during this time. The results are given in table 1.

In Test 2 the initial exposure and the exposure 1 day after treatment required only 15 minutes to kill 100 per cent of the flies. When the flies were exposed to the vapor action in both Tests 3 and 4, it required 60 minutes to obtain 100% kill for the same intervals. On the 13th and 21st days after application it required 180 minutes to obtain 100% kill in all three tests.

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[2] Associate Entomologist and Associate Professor of Entomology.

Table 1.—Toxicity of Diazinon vapors to horn flies under laboratory conditions. Clemson, S. C. 1955.

TEST NUMBER	TREATMENT	DAYS AFTER APPLICATION[a]	EXPOSURE REQUIRED TO KILL 100%[b] (MINUTES)
1	Check[c]		
2	Treated cage (Contact and vapor action)	0	15
		1	15
		4	90
		6	90
		13	150
		21[d]	180
3	Treated panels (Vapor action)	0	60
		1	60
		4	120
		6	150
		13	150
		21	180
4	Cage in treated box (Vapor action)	0	60
		1	60
		4	120
		6	150
		13	150
		21	180

[a] Initial treatment August 30, 1955.
[b] Used 200 horn flies in each test.
[c] Horn flies in check cage lived for at least 8 hours.
[d] Tests discontinued due to lack of horn flies.

Table 2.—Toxicity of Diazinon to horn flies in a diary barn. Clemson, S. C. 1955.

Treatment	Days After Application[a]	Per Cent Kill After:[b] 45 Min.	1 hr.	1½ hrs.	2 Hrs.
Check[c]					
Diazinon, 0.5%	0	40	100		
	1	80		95	100
	2		50		100
	6		50		100
	13				0
	31				0

[a] 200 horn flies used in each cage.
[b] Initial treatment August 31, 1955.
[c] Check cage maintained on each day barn was checked.

Fields Tests.—Field tests were designed and conducted along with the laboratory tests. A new dairy barn was selected that had never been treated with any organic phosphate or chlorinated hydrocarbon insecticides. This cinder-brick barn was 36 by 20 by 7 feet which is an average size barn in South Carolina. The barn was sprayed with 0.5% suspension of Diazinon wettable powder using a 50-gallon hydraulic sprayer. The insecticide was applied at 300 p.s.i. at the rate of 1 gallon per 360 square feet. A two-nozzle orchard spray gun was used to apply the material. The barn was treated 4 hours before the cows entered for the evening milking.

Horn fly counts taken just prior to the time the cows entered the barn averaged 68 per animal. There were 21 cows in the herd and each cow remained in the barn only 15 minutes during each milking. No horn flies were observed dropping from the cows while in the barn. Fly counts made the following morning and again in the afternoon averaged 9 flies per cow. Apparently this 30-minute exposure was sufficient to cause death of the horn flies when the cows returned to the field.

A cage containing 200 horn flies was placed in the center of the barn during the evening milking on the day of application and at intervals of 1, 2, 6, 13, and 21 days following the initial application. The results of this experiment are given in table 2. All of the flies were dead after a 1-hour exposure in the barn on the day of application. Two hours were required to obtain the same kill on the sixth day. After 13 and 21 days the 2-hour exposure did not give any kill of horn flies at the end of a 4-hour holding period.

A check cage of 200 flies was placed under a shade tree approximately 50 yards from the barn during each exposure. Horn flies in the check cage lived for at least 7 hours. Horn fly counts made on the animals 8 days after the initial application averaged 18 flies per cow, and after 13 days averaged 65 flies per cow or approximately the same population as when the test started.

Summary.—Observations on the horn fly population on cows milked in barns sprayed with a 0.5% suspension of Diazinon wettable powder for house fly control revealed a considerable reduction following application. This fly remains on the host almost constantly, therefore a fumigating effect was indicated.

Laboratory and field experiments conducted late in the season have proven that the vapors of Diazinon when sprayed as a 0.5% wettable powder suspension are highly toxic to horn flies. Twenty-one days after application exposure to Diazinon vapors for 3 hours was sufficient to kill 100% under laboratory conditions. When a barn was sprayed with this material, a ½-hour exposure of horn flies on animals reduced the population from 68 to 9 horn flies on the day following application.

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Control of Horn Flies on Cattle with Treated Rubbing Devices[1]

Wm. J. Goodwin[2]

The horn fly, *Siphona irritans* (L.), is the most abundant species of Diptera found on cattle in South Carolina. This fly occurs in large numbers on untreated animals beginning in early May and continuing through September. These insects annoy cattle by their presence as well as by causing a reduction in production due to their bloodsucking habit. Lindquist & Hoffman (1954) stated that horn flies can cause a 10 to 20% loss in milk production, and Laake (1946) reported that control of large populations of horn flies resulted in increased weight gain of beef cattle by 42 to 70 pounds.

The use of treated rubbing devices has proven to be an effective method of controlling horn flies under certain conditions. Rogoff & Moxon (1952) obtained excellent results with these devices under range and feed lot conditions in South Dakota. DeFoilart (1954) found that when the devices were installed in large, bushy, rough pastures, effective control was not obtained. Gressette & Goodwin (1955) demonstrated excellent control of cattle lice on dairy and beef cattle using these devices in South Carolina.

The use of butoxy polypropylene glycol alone and in combination with other insecticides and repellents has been found to be effective against the horn fly. Goodwin *et al.* (1952) working in New York found this material effective against this species when used as a water emulsifiable spray. Granett *et al.* (1955) have shown that various formulations of butoxy polypropylene glycol were effective against horn flies on dairy cattle when used in treadle sprayers. The purpose of the research reported in this paper was to test the effectiveness of these devices for the control of horn flies and other flies on beef cattle and dairy heifers, and to determine if the addition of butoxy polypropylene glycol to emulsifiable formulations of DDT and methoxychlor increased the effectiveness of these materials in controlling the horn fly.

Materials and Methods.—Emulsifiable concentrates of the following materials were used: 40% butoxy polypropylene glycol plus 20% DDT, 40% butoxy polypropylene glycol plus 20% methoxychlor, 20% DDT, 20% methoxychlor, 50% Perthane, and 57% malathion. Number 2 fuel oil was used to dilute these formulations to the desired concentrations shown in table 2.

The inverted "V" or louse type device described by Hoffman (1954) and Gressette & Goodwin (1955) was used in this experiment. These devices were installed in beef pastures located at Clemson and in dairy heifer pastures belonging to the State Prison Farm, Boykin, South Carolina. They were installed near the source of water, salt or minerals, or in other locations frequented by the animals.

The number of animals using the devices ranged from 10 to 60. The beef animals were breeding herds of purebred Angus and Hereford, and the dairy heifers were all Holsteins.

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[2] Associate Entomologist and Associate Professor of Entomology.

Table 1.—Pints of material per linear foot of cable required to maintain a treated rubbing device June 13 to August 6, 1955. Clemson, S. C.

Material and Concentration	Pints Used			Number of Animals	Amount per Animal
	Initial Treatment	Additional Treatments[a]	Total		
BPG[b]—10% plus DDT—5%	0.57	2.53	3.10	16	0.19
BPG—10% plus DDT—5%	.50	1.98	2.48	12	.21
DDT—5%	.60	2.25	2.85	25	.11
DDT—5%	.50	2.92	3.42	28	.12
Perthane 5%	.40	2.55	2.95	11	.27
Malathion 5%	.50	2.90	3.40	60	.06

[a] Applied at 10–14 day intervals.
[b] Butoxy polypropylene glycol. A product of Carbide and Carbon Chemical Company, New York, N. Y.

The devices were treated at the beginning of the fly season with 0.4 to 0.6 pints of material per linear foot of cable and were retreated when the cables became dry which was usually at 10 to 14 days. The method employed in determining when to retreat the devices was to grip the cable in one hand and if the hand did not feel oily, then it was time to retreat the cable. Weather conditions and the number of animals using the device determined the amount of material required to maintain them. Usually 0.15 to 0.30 pints of material per linear foot was required each time the devices were retreated.

Horn fly counts were made on 10 animals of each treatment, three times per week, during the summer. Untreated herds located in the same vicinity were employed as checks.

Experimental Data.—In order to determine if the addition of butoxy polypropylene glycol increased the residual action of DDT and methoxychlor on the treated rubbing devices, accurate records were maintained on the amount of material required to treat each device. This information is shown in table 1. The data indicate very little difference in the amount of material required to maintain devices treated with butoxy polypropylene glycol plus DDT as compared to DDT alone. The average total amount of butoxy polypropylene glycol plus DDT was 2.79 pints per linear foot and for DDT alone it was 3.14 pints. The devices treated with butoxy polypropylene glycol plus DDT treated an average of 14 animals, whereas the devices treated with DDT treated an average of 26.5 animals.

Table 2.—Control of horn flies on beef cattle and dairy heifers with treated rubbing devices. Clemson, S. C. 1955.

Material and Concentration	Weeks Tested	Total Number of Horn Flies	Per Cent Reduction
Beef cattle			
Check	10	12,242[a]	
BPG[b]—10% DDT—5%	10	238	98.0
BPG—10% DDT—5%	10	62	99.5
DDT—5%	10	136	98.8
DDT—5%	10	863	92.9
Perthane—5%	9	20	99.8
Malathion—5%	9	21	99.6
Dairy heifers			
Check	9	5,921[a]	
CFR—10% Methoxychlor—5%	9	327	94.5
Methoxychlor—5%	9	480	91.8

[a] Counts represent the number of horn flies on 10 animals, counted 3 times per week, for the number of weeks indicated.
[b] Butoxy polypropylene glycol.

When the number of animals using a device is increased the amount of material required per animal to maintain the device is reduced. It required 3.42 pints per linear foot of DDT to treat 28 animals, giving an average of 0.12 pints of material per animal. When 3.4 pints of malathion were used on 60 animals the amount required per animal was reduced to 0.06 pints.

All of the materials tested gave satisfactory control of horn flies. When butoxy polypropylene glycol was added to DDT for use on beef cattle the control was slightly greater than with the DDT alone. Butoxy polypropylene glycol plus DDT gave an average of 98.7% reduction and DDT gave 95.9. The addition of butoxy polypropylene glycol to methoxychlor gave 94.5% reduction whereas methoxychlor alone gave 91.9%. Perthane and malathion gave better than 99% reduction of horn flies.

Counts were made on the house fly, stable fly, and horse flies, but these species did not occur in large enough numbers to warrant reporting.

Summary.—Treated rubbing devices were found to be effective in controlling horn flies on beef cattle and dairy heifers. The amount of material required to maintain a device for 8 weeks varied from 0.06 to 0.27 pints per linear foot of cable per animal depending on the number of animals using the device. All of the materials tested gave satisfactory control of horn flies. The addition of butoxy polypropylene glycol to DDT and methoxychlor emulsifiable formulations gave a slight increase in the effectiveness of these materials.

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Laboratory Studies on *Heliothis zea* (Boddie) and *H. virescens* (F.)

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Cotton and tobacco, the two major cash crops in the South, have few insect pests in common. The larvae of two of these pests, *Heliothis zea* (Boddie) (Corn Earworm, Bollworm or Tomato Fruitworm) and *H. virescens* (L.) (Tobacco Budworm), so closely resemble each other that a microscopic examination is required for positive identification. Field populations of these pests are often completely mixed on tobacco and to a lesser degree on cotton. Thus, it is possible that much of the work on bollworms or tobacco budworms in reality is dealing with a mixed population rather than a single species.

Brazzel *et al.* (1953) reported that the tobacco budworm was less susceptible to DDT than the bollworm. Toxaphene and

Table 1.—Effect of topical applications of insecticides on *Heliothis* virescens and *H. zea*.

Insecticide	Dosage γ/Gram	*H. virescens* Per-Cent Kill	*H. virescens* LD-50 γ/Gram	*H. zea* Per Cent Kill	*H. zea* LD-50 γ/Gram
Toxaphene	1,000			40	
	2,000	21		33	
	4,000	33		74	
	8,000	41	18,000	80	2,000
TDE	800			36	
	1,600			66	
	3,200	5		40	
	6,400	22		53	
	12,800	45	17,000		3,000
DDT	625			57	
	1,250	16		80	
	2,500	19		71	
	5,000	42		68	
	10,000	65	6,500		3,000
Endrin	10			15	
	20			57	
	40	20		74	
	80	29		80	
	160	42			
	320	75	180		17
Malathion	50	15		29	
	100	38		53	
	200	50		57	
	400	78	160	72	130
Bayer L13/59	20	5		33	
	40	29		66	
	60	33			
	80	68	60	87	30
Bayer 17147	10	7		12	
	20	29		48	
	40	41		50	
	80	57	54	74	40
Shell OS-2046	2	16		13	
	4	30		46	
	6	57		75	
	8	82	4.8	67	4.8

BHC-DDT-sulfur mixture were reported as being equally toxic to both species. The investigations reported herein were initiated to determine the comparative contact toxicity of eight insecticides to the bollworm and tobacco budworm under laboratory conditions.

METHODS.—Sixth instar larvae of *H. zea* and *H. virescens* weighing 250 to 450 milligrams were collected from tobacco seed heads during September and October and placed individually in shell vials. *H. virescens* was generally more abundant than *H. zea*. Worms which showed evidence of parasitism were eliminated from the tests. Each worm was weighed and identified under a binocular microscope. Identification was based on the presence or absence of microspines on the abdominal tubercules. The worms were then transferred to 4-ounce jars to await treatment.

Technical materials were dissolved in methyl ethyl ketone and were applied topically to the abdominal dorsum by the method of Trevan (1922). All materials were applied on a microgram per gram of worm basis. To facilitate the procedure, the concentrations were adjusted so that each larva received one micrometer unit for each 10 milligrams of weight. Thus, a worm weighing 450 milligrams would receive 45 units or 10 microliters of solution. All materials were tested at four concentrations, each concentration being twice that of the preceding one in an ascending series. Dosage rates were changed by increasing the amount of toxicant in the solvent with the exception of the highest rates of DDT, TDE, and toxaphene which were not sufficiently soluble in the solvent to obtain the desired concentration. In these cases the next lowest concentration was used at twice the volume. Thirty-five or more *H. virescens* and 15 or more *H. zea* larvae were used at each concentration. After treatment each worm was placed in a separate jar and provided with fresh portions of tobacco seed heads daily during the test period. The holding temperature was maintained at 90° F. and 75% R. H. No mortality was observed among worms treated with the solvent alone at two and four times the volume used in the tests. A worm was considered dead when it no longer responded to probing with a needle.

The LD-50 at 48 hours was determined from eye-fitted dosage mortality curves. Such approximations have been shown by Bliss (1935) to be sufficiently accurate for conclusions similar to those made here.

RESULTS AND DISCUSSION.—The results of the tests and the derived LD-50 values are shown in table 1. With the exception of Shell OS-2046 all materials were more toxic to the bollworm than to the tobacco budworm. With the phosphorous compounds the differences were not as pronounced as with the chlorinated hydrocarbons. The chlorinated materials, with the exception of endrin, showed poor contact toxicity. Field control of both species of larvae with the chlorinated hydrocarbons is considerably better than indicated by these tests. This may be explained by the fact that in the field the worms are subjected to stomach action of the poisons as well as contact action. Also, field control is directed primarily against smaller worms than those tested in this test. Although the materials were applied on a microgram per gram of worm basis, there was some indication in the tests that the smaller larvae were more susceptible than the larger worms.

The differences in susceptibility between the two species of worms could explain some of the cases of poor control experienced by farmers. If a grower was treating for bollworms, when actually his crop was infested by tobacco budworms, it might be expected that the desired control might not be attained.

SUMMARY.—Topical applications of eight insecticides were made to sixth instar larvae of *Heliothis virescens* and *H. zea*. Shell OS-2046 was the most toxic material tested and was equally toxic to both species. All other materials were more toxic to *H. zea* than to *H. virescens*, but the phosphates showed less differential than the chlorinated hydrocarbons.

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Control of Mites Infesting Earthworm Beds[1]

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Commerical earthworm producers have recently expressed much concern over the presence of large numbers of mites in earthworm beds. At present the exact economic relationship of these mites to the commercial production of fishing worms is not clear; however, when present in large numbers they become obnoxious pests to the worm producers. In 1954 preliminary tests

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were conducted to determine the effect of several acaricides on mites infesting earthworm beds and on the earthworms, and to determine species of mites infesting earthworm beds.

PROCEDURE.—Approximately 50 gallons of mite-infested soil was collected from earthworm beds. The soil was mixed thoroughly and 1 gallon of this mixed soil was placed in each of 40 two-gallon glazed ceramic pots. Adult earthworms were placed in each container. A hole at the bottom of each pot was stoppered with cheese cloth to permit drainage of excess water, yet prevent escape of mites and worms. Approximately 25 grams of corn meal was added to each container for worm food.

Ten treatments, including an untreated check, were replicated four times. The compounds used in the tests were Metacide, malathion, parathion, and Aramite. Metacide and malathion were applied as emulsion sprays; parathion was applied as emulsion and wettable powder sprays; and Aramite was applied as a wettable powder spray only. Various concentrations of these materials were tested.

The soil in the pots was thoroughly wet with water 1 to 2 hours prior to acaricidal treatment. The acaricides were applied to the surface of the soil with a 5-gallon power sprayer equipped with a hand gun. The rate of application was 1 gallon of material per 12 to 15 square feet of surface area.

Forty-eight hours after treatment, the soil was poured from each pot and the number of live worms determined. The soil was then thoroughly mixed and a ½-pint sample was removed. One cubic inch of soil from this sample was then examined to determine the number of live mites. The soil sample was placed in a petri dish and separated with teasing needles. The petri dish was placed over a white background, and all live mites were then counted. Seven days after treatment, a second check on the number of live mites and worms present was made.

Two earthworm beds currently in production were treated with acaricides for observation. Each bed with a surface area of approximately 210 square feet was heavily infested with mites. Bed "A" was treated with Metacide, 1 pint of 50% emulsifiable concentrate per 100 gallons of water. Bed "B" was treated with parathion, 1 pint of 25% emulsifiable concentrate per 100 gallons of water. The treatment procedure and rate of application for the beds were the same as those used on the potted soil. Observations of the effect of treatment on mites and earthworms were made 48 hours after treatment.

RESULTS.—Three species of mites representing three families were collected from the earthworm beds. The species occurring in the largest number was *Caloglyphus anomalus* Nesbitt of the family Acaridae. The two remaining species were identified[2] as *Macrocheles* (sp.) and *Parasitus* (sp.) belonging to the families Macrochelidae and Parasitidae, respectively. The two latter species are predators and might possibly attack earthworms. The acarid mite, however, probably feeds on worm food, fungi, and organic matter in the bed.

Table 1.—Average numbers of live mites and earthworms following acaricidal treatment. Auburn, Alabama, 1954.

Treatment[a] and Concentration	Average Number After Treatment			
	Mites per Cubic Inch of Soil		Live Worms per Pot[b]	
	48 Hrs.	7 Days	48 Hrs.	7 Days
Check	412.3	358.5	10.0	10.0
Metacide, 2½% Emul.	0.0	0.8	7.8	0.0
Metacide, 1% Emul.	0.3	0.5	8.3	0.3
Metacide, 1 pt. 50% E.C./ 100 gal. water	3.0	2.5	10.0	10.0
Malathion, 2½% Emul.	4.3	4.5	0.5	0.0
Malathion, 1% Emul.	14.5	16.8	1.8	1.3
Parathion, 1% Emul.	0.0	0.0	0.0	0.0
Parathion, 1 pt. 25% E.C./ 100 gal. water	0.3	0.3	10.0	8.3
Parathion, 2 lb. 15% W.P./ 100 gal. water	1.3	1.0	10.0	10.0
Aramite, 2 lb. 15% W.P./ 100 gal. water	299.3	265.5	9.8	9.3
L.S.D. at 5% level	30.21	100.67	1.51	1.26
at 1% level	40.79	135.95	2.04	1.69

[a] Treatments applied as sprays at rate of 1 gallon per 12 to 15 square feet of soil surface.
[b] Ten active worms placed originally in each pot.

Results of the tests conducted in potted soil are presented in table 1. All acaricidal treatments with the exception of Aramite resulted in a highly significant reduction in mite population. Metacide at all concentrations tested gave a high degree of mite kill; however, only the lowest concentration (1 pint of 50% emulsifiable concentrate per 100 gallons of water) did so without significantly reducing the number of earthworms. Malathion proved very effective as an acaricide, but it was highly toxic to the earthworms at the concentrations used in these tests.

A 100% kill of both mites and earthworms resulted from the use of 1% parathion emulsion spray. Parathion, 1 pint of 25% emulsifiable concentrate per 100 gallons of water, was completely effective in killing the mites, while it reduced the worm population an average of only 17.5%. Parathion, applied as a wettable powder spray at the rate of 2 pounds of 15% per 100 gallons of water, also gave a highly significant mite kill. All worms in the soil receiving this treatment were still active 7 days after treatment. Aramite did not significantly reduce earthworm numbers; it also failed to effectively reduce mite populations. From observations of two productive worm beds made 48 hours after treatment with Metacide and parathion emulsion sprays, it was estimated that the mite population was reduced by 80 to 90% after one application. No dead worms were observed.

SUMMARY.—An experiment was conducted to determine the effect of acaricides on mites infesting earthworm beds and on the earthworms present, and to determine the species of mites infesting earthworm beds. Tests consisted of the treatment of potted soil containing mites and earthworms. Earthworm beds in production were also treated for observation. Various rates of Metacide, malathion, parathion, and Aramite were tested.

Three species of mites were collected from earthworm beds. The species *Caloglyphus anomalus* Nesbitt was the most prevalent.

All materials with the exception of Aramite effectively reduced mite populations. All worms were still active in pots 7 days after treatments of Metacide, 1 pint of 50% emulsifiable concentrate per 100 gallons of water, and parathion, 2 pounds of 15% wettable powder per 100 gallons of water. Malathion and higher concentrations of Metacide and parathion significantly reduced worm populations. Aramite was not effective as an acaricide but did not reduce the number of earthworms.

An estimated 80 to 90% control of mites was obtained in earthworm beds in production by the use of sprays of Metacide, 1 pint of 50% emulsifiable concentrate per 100 gallons of water, and parathion, 1 pint of 25% emulsifiable concentrate per 100 gallons of water. No dead earthworms were evident.

[2] Identification of mites and notes on their habits were furnished by Dr. Edward W. Baker of the Insect Identification and Parasite Introduction Section, Entomology Research Branch, U. S. Department of Agriculture.

The European Corn Borer in Alabama[1]

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The European corn borer, *Pyrausta nubilalis* (Hbn.), was first reported in Alabama in 1950 (Beck 1951). A few larvae were found by personnel of the Alabama Department of Agriculture and Industries and the U. S. Department of Agriculture during a fall survey in Lauderdale and Madison counties, which are

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adjacent to Tennessee. Since its discovery in Alabama, the insect has been watched rather closely. Apparently there was very little spread until 1954. By the fall of 1955 it had been found in 14 northern Alabama counties.

From its discovery in 1950 through 1953, the corn borer caused no apparent losses in Alabama. The first serious economic damage occurred on pimento pepper in the fall of 1954. Approximately 25% of the pimento pods in some fields were infested in early October of that year. In 1955 the borer caused considerably more damage. In some pimento fields, 65% of the pods and in many corn fields over 60% of the stalks were infested. As much as 25% loss occurred in some fields of grain sorghum.

Damage to corn caused by the borer in Alabama was characteristic of that in other corn-growing areas. The damage in grain sorghum was similar to that reported by Painter & Weibel (1951). In pimentos the injury was typical of that described by Hodgson (1928) in peppers. The eggs are laid on the pimento leaves and the larvae migrate to the pods. The larvae bore into the stems or calyxes and downward into the fruits or enter the fruits directly by boring under the calyxes. The larvae feed inside the pimento pods on the cores as well as on the flesh of the pods. The larvae are very small and in the early instars when they enter the pimento pods, so the masses of frass are much smaller and less noticeable than those left when larger borers enter corn stalks. For this reason growers seldom notice the injury in pimentos when they are first attacked. As the larvae increase in size, the pods begin to deteriorate.

The corn borer in pimentos caused severe losses to Alabama farmers in 1955. Almost all of the pimento acreage is grown under contract to canners. Canners stopped buying pimentos in the middle of the harvesting season because of the corn borer. Preliminary experiments indicated that DDT would control the insect on pimentos, but the use of DDT created the problem of residues on the canned product.

A cooperative program was conducted by the Agricultural Experiment Station of the Alabama Polytechnic Institute, Pomona Products Company of Griffin, Georgia, and the Food and Drug Administration to determine DDT residues on pimentos. Two lots of pimentos were treated with DDT emulsions by dipping the pods into the emulsions. One lot was dipped in an emulsion containing 2 pounds of DDT to 20 gallons of water; another lot was dipped in an emulsion containing 4 pounds of DDT to 20 gallons of water. The pods were air-dried and processed by Pomona Products Company along with some untreated pimentos. The canned pimentos were analyzed for DDT by the Food and Drug Administration Laboratory in New Orleans. No DDT was detected in any of the samples. Based on this work, it was concluded that there would be no DDT residues on processed pimentos regardless of the amount of DDT used in the field to control insects.

Beginning about mid-June of 1955, at which time the first generation borers were in the last instar, the life history of the corn borer was followed closely in Alabama. Moths of the first generation borers appeared about July 1. Second generation moths appeared about the middle of August and laid eggs for the third generation borers. The first and second generation borers appeared to be confined to corn. The second generation moths laid third-generation eggs primarily on sorghums and pimento peppers. By mid-September third generation borers were beginning to go into the fifth instar in sorghums and pimento peppers. At this time, fifth-instar larvae were still present from previous generations in corn. No pupae from the third generation were found in corn, sorghums, or pimentos in 1955. Thus, the corn borer had three complete generations in Alabama in 1955; whereas, in Kentucky the insect has only two broods per year and sometimes a very small third (Ritcher 1947).

SUMMARY.—The European corn borer, *Pyrausta nubilalis* (Hbn.), was first found in two counties in Alabama in 1950. By the end of 1955 it had been found in 14 counties in the northern part of the state. The first noticeable economic damage from the insect occurred on pimento pepper in the fall of 1954. In 1955 the corn borer did economic damage to corn, grain sorghum, and pimento pepper.

Preliminary experiments in 1955 indicated that DDT would give control of the corn borer on pimentos. Residue determinations showed that there was no DDT residues in the processed pimentos even when treated at rates in excess of those needed for borer control.

The corn borer had three complete generations in Alabama in 1955. The first two generations were confined to corn. The third was found primarily on sorghums and pimento peppers.

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An Improved Method for Rearing Cockroaches[1]

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The original method of rearing cockroaches in test-tube cages (Noland *et al.* 1949) has been used by the author for a number of years with good results. A disadvantage however was the requirement for a relatively large shelf area in a warm room for storage of the racks. Furthermore the water tubes sometimes leaked, resulting in spoiled diets and death of the insects. The improved design illustrated in figure 1 was developed to correct these deficiencies, and has given excellent service during the past 2 years of use. The rearing tubes are made from 25×200 mm. test-tubes having the rounded ends removed. A disc of 60 to 100 mesh screen is sealed over the opening by use of a 50:50 mixture of molten rosin and beeswax, or alternatively by a perforated 1-inch rubber cap (E. H. Sargent & Company) in which case the cap and screen may both be easily removed for cleaning. The diet tubes are 10×50 mm. The watering device consists of a rubber stopper containing a 15×45 mm. vial which in turn holds a wick made from a short piece of No. 2 dental cotton roll. It is usually necessary to make a single perforation in the wick with a needle to aid the flow of water.

For the convenient maintenance of an inbred stock colony, pairs of adult cockroaches are kept in the rearing tubes and fed a complete dog food such as "Friskies" or "Gro-Pup." Reproduction is poor in cockroaches reared on "Synthetic Diet V" (Noland & Baumann 1949) so that only a complete dog food is used for the stock colony. When an egg-sac hatches the nymphs (usually about 40) are divided into eight experimental groups which thus occupy one rack. With one group serving as a control there remain seven experimental groups for the determination of growth rate, time of maturation, reproduction or other performance data resulting from experimental procedures.

Growth rate is conveniently determined by weighing each group of nymphs after carbon dioxide anesthesia at a specified age, such as 30 days. Newly hatched nymphs of *Blattella ger-*

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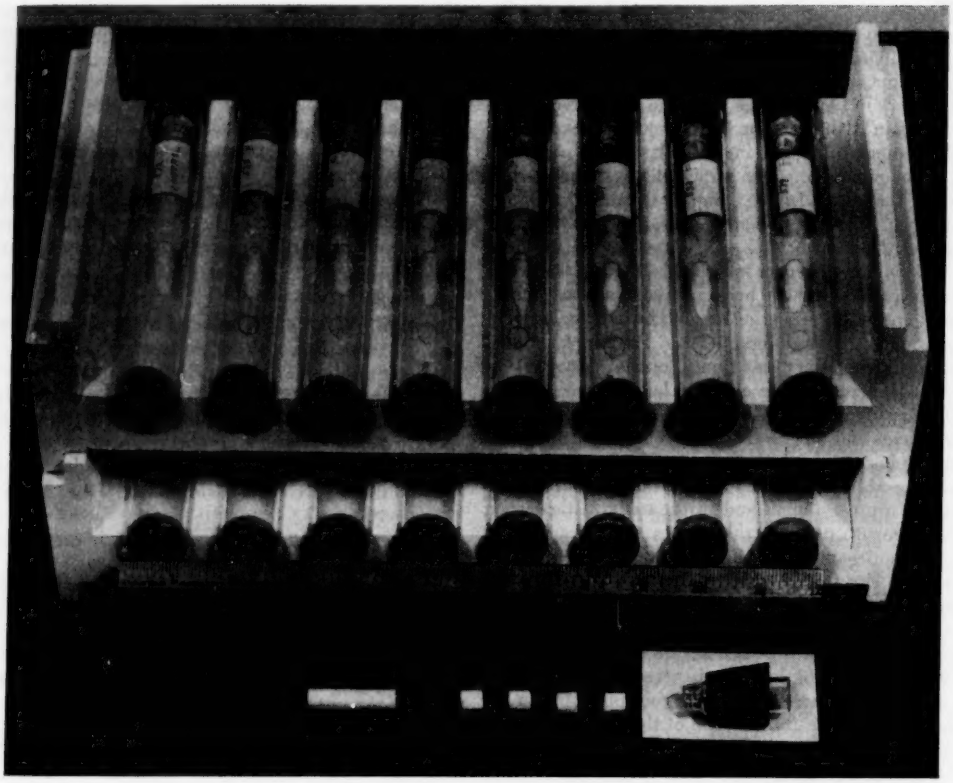

FIG. 1.—Improved design of cockroach rearing cages and racks, showing details of the watering device.

manica (L.) weigh about 3 mg. After the imaginal moult, which occurs in about 40 days at 30° C., the males weigh about 40 mg. and the females about 60 mg. Although 30-day-old female nymphs weigh more than male nymphs of the same age, the age at maturation is the same for both sexes (Noland *et al.* 1949). The two criteria of growth and maturation taken together therefore yield the necessary information on relative growth-rates of experimental versus control groups.

Perhaps the most important aspect of the new design is its compactness. The author has been able to continue sterol metabolism experiments (Noland 1954) in a hospital laboratory simply by stacking the racks in a large incubator instead of utilizing shelf space in a warm room which had been necessary for previous work. The method is highly recommended for any small scale toxicity or dietary studies on the German cockroach especially if a genetically controlled population is desired or if the environmental conditions must be strictly controlled.

ACKNOWLEDGEMENT.—The author would like to express his appreciation to Donald E. Van Scotter who suggested some refinements in the design of the apparatus.

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Parasites from Two Jack-Pine Budworm Outbreaks on the Upper Peninsula of Michigan[1]

A. T. DROOZ and D. M. BENJAMIN,[2] *Lake States Forest Experiment Station*[3]

Following the recognition of the jack-pine budworm, *Choristoneura pinus* Free., as a species distinct from the spruce budworm, *C. fumiferana* (Clem.), interest in reporting the parasites of the former species has been renewed (Walley 1953, Benjamin & Drooz 1954). Parasites reported here were dissected from larvae or reared from pupae collected in the Upper Peninsula of Michigan in 1953.

In 1952 an outbreak of the jack-pine budworm was detected in northern Luce County (Anonymous 1953). By 1953 this outbreak covered approximately 6,000 acres of natural jack pine. Simultaneously, another outbreak covering about 1,200 acres was reported in Chippewa County, 50 miles to the southeast. The evaluation of parasites of the budworm in Luce County was begun on July 16 with the collection of late-instar larvae at eight roadside stations, spaced approximately one-half mile apart, through the center of the epidemic area. Pupal collections were made at nine roadside stations between July 17 and 22. In Chippewa County, pupal collections were made at six roadside stations throughout the epidemic area on July 22. No overwintering larvae or eggs were obtained in either outbreak area.

Dissection of larvae collected in Luce County showed that

[1] Accepted for publication March 22, 1956.

[2] Since this article was written, Dr. Benjamin has become a member of the faculty at the University of Wisconsin.

[3] Maintained at St. Paul 1, Minnesota, by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of Minnesota.

Table 1.—Dipterous parasites of late-instar jack-pine budworm larvae in Luce County on the Upper Peninsula of Michigan.

SPECIES OF DIPTERA	NUMBER[a]	PER CENT OF LARVAE PARASITIZED
Larvaevoridae		
Aplomya caesar (Ald.)[b]	10	4
Phryxe pecosensis T.T.	2	1
Sarcophagidae		
Agria affinis (Fall.)	2	1

[a] 282 larvae were dissected.
[b] Identified by C. W. Sabrosky, Entomology Research Branch, Section of Insect Identification and Parasite Introduction, U. S. Department of Agriculture.

three species of dipterous parasites, *Aplomya caesar* (Ald.), *Phryxe pecosensis* T.T., and *Agria affinis* (Fall.), were present in the budworm population (Table 1). Although overwintering larvae were not collected, the ichneumonid *Glypta fumiferanae* (Vier.) was found in larvae collected in Luce County.

The relative abundance of 11 hymenopterous pupal parasites reared from Luce and Chippewa County collections is indicated in table 2. Many of the known species of parasites that are commonly reported attacking the spruce budworm have been found to attack the jack-pine budworm. However, some species which had been found abundant in one area were noticeably absent in other areas. The larvaevorid, *Aplomya caesar*, was reared from spruce budworm taken in New York in 1946, 1947, and 1948, and from the same host in Maine between 1948 and 1951 (Jaynes & Drooz 1952). This parasite was not obtained from jack-pine budworm larvae collected in Lower Michigan from 1951 through 1952 (Benjamin & Drooz 1954). However, it accounted for the highest percentage of parasitism in that pest among the Upper Michigan larval samples. Parasitism by the ichneumonid, *Itoplectis conquisitor* in the Luce County (1-year-old) outbreak is five times as great as that in the newly discovered Chippewa County outbreak.

Annual collections of larvae and pupae will be continued to provide additional information concerning the biology of the host, *Choristoneura pinus*, and its parasite complex.

Table 2.—Pupal parasites of the jack-pine budworm in Luce and Chippewa Counties in Upper Michigan.

SPECIES[a]	LUCE COUNTY[b]		CHIPPEWA COUNTY[c]	
	Number	Per Cent of Pupae Parasitized	Number	Per Cent of Pupae Parasitized
Hymenoptera: Ichneumonidae				
Apechthis ontario (Cress.)	0	0	1	T[d]
Gelis tenellus (Say)	1	T	0	0
Itoplectis conquisitor (Say)	198	21	21	4
Phaeogenes hariolus (Cress.)	1	T	2	T
Scambus hispae (Harr.)	5	1	1	T
Unidentified larvae	0	0	3	1
Hymenoptera: Chalcidoidea				
Amblymerus verditer (Nort.)	14	2	24	4
Brachymeria ovata (Say)	1	T	0	0
Habrocytus phycidus Ashm.	11	1	1	T
Syntomosphyrum esurus Riley	1	T	3	1
Unidentified larvae	1	T	2	T
Diptera: Sarcophagidae				
Agria affinis (Fall.)	153	17	64	11
Pupal mortality (unknown causes)	169	18	36	9

[a] The aid of P. W. Oman, L. M. Walkley, and B. D. Burks of the Entomology Research Branch, Section of Insect Identification and Parasite Introduction, U. S. Department of Agriculture for determination of specimens is appreciatively acknowledged.
[b] 923 pupae examined.
[c] 577 pupae examined.
[d] Trace (less than 0.5%).

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Systemic Insecticide Studies for Control of Vectors and Sugarcane Mosaic in Louisiana[1]

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The rusty plum aphid, *Hysteroneura setariae* (Thos.), is a carrier of sugarcane mosaic disease in Louisiana. Although this aphid is the least efficient of the four known insect vectors of the disease, as reported by Ingram *et al.* (1951), it is probably the most important because of its greater abundance.

In June 1952 an experiment was conducted to determine the value of the systemic insecticide Systox for the control of this aphid. The experiment was located in a field of variety C. P. 36/13 sugarcane, which had a uniform although light infestation. It was of a random-block design with five replications of each of two treatments and of the check. Each plot consisted of a single row of cane, 12 feet long, separated from the other plots by side buffers of one row. Systox containing 48.1% demeton was used, 1 pint in 20 gallons in one treatment and 1 quart in the other. It was applied on June 5 with a hand air-compressed sprayer. The 20-gallon-per-acre dosage was enough to cover the foliage thoroughly with no runoff. Each examination consisted of three samples of 10 consecutive plants in each replicate, or a total of 150 plants per treatment or check. The percentages of the plants infested at different periods after treatment are given below:

Days	*1 Pint*	*1 Quart*
1	70	80
11	90	90
19	95	95
33	33	53
47	9	4

The maximum control was obtained after 19 days. Practically no control was noted after 47 days.

In 1953 a similar experiment was conducted in the same variety of sugarcane to determine the comparative value of Metacide, schradan, and Systox in control of the rusty plum aphid. One quart of the technical material in 20 gallons of water was applied per acre. The results of this experiment are presented in table 1. On the day after treatment the following numbers of plants per 150 with colonies of dead aphids still clinging

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[2] In cooperation with the Louisiana Agricultural Experiment Station and Field Crops Research Branch, Agr. Res. Serv., U.S.D.A.

Table 1.—Percent control of rusty plum aphid by single applications of systemic insecticides to sugarcane foliage on June 16, 1953.

INSECTICIDE	1 DAY	15 DAYS	29 DAYS	42 DAYS
Metacide	100	88	23	0
Schradan	78	47	50	31
Systox	100	100	45	63

to the collar lobes were recorded: Metacide 12, Systox 8, schradan 5, and untreated checks 0.

The insecticides apparently had no effect on the gray sugarcane mealybug, *Pseudococcus boninsis* Kuw., as a general infestation persisted throughout the examination period.

Based on these findings, studies were initiated to determine if the spread of sugarcane mosaic could also be checked by controlling its vectors. Successful control of the vectors might provide an economical method of growing mosaic-free sugarcane for seed. In the fall of 1953 a 3-acre planting of mosaic-susceptible variety Co. 290 with a low infection of mosaic was made in an area of historic heavy spread of the disease. On April 13, 1954, ¼-acre plots were set up in this planting; three of the plots were scheduled to receive three applications at 3-week intervals of Systox at the rate of 2 pints in 30 gallons of water, and three alternate plots were used for checks. All disease-infected stools were rogued out before treatment. The insecticide was applied on April 13 and May 10 and 29 with a low-gallonage power sprayer.

On May 20, 100 plants in each plot were examined for vector infestation. A 100% control of the rusty plum aphid was obtained. In a second examination on May 28 there was an 80% control of the rusty plum aphid and the corn leaf aphid, *Rhopalosiphum maidis* (Fitch). No vectors were observed on host plants in and around the experimental planting during the spraying period. On June 16 mosaic infection averaged 2.9% in the sprayed plots and 2.1% in the checks. The high control of mosaic vectors obtained during May, normally the peak of mosaic spread, was not reflected in a reduced incidence of the disease.

Another experiment was conducted in variety Co. 290, in which alternate ¼-acre plots were treated with 2 pints of Systox containing 21% of demeton in 30 gallons of water per acre on April 10 and 30 and May 25, 1953. The insecticide was applied with a low-gallonage power sprayer. The experiment was discontinued in June owing to a high initial mosaic infection and the general absence of insect vectors. However, samples from the treated plots were obtained, processed, and frozen on November 5, and analyses[3] for Systox residues were obtained in 1954. The residues in parts per million were: Bagasse 0.2, juice 0.2, syrup 0.4, molasses 2.0, mud 0.2, and sugar 2.0.

These experiments show that, although Systox gave good control of the rusty plum aphid, an important vector of sugarcane mosaic there was no control of the disease. The insecticide was recovered by chemical analysis in the molasses, syrup, and sugar samples processed from field-treated sugarcane. Metacide and schradan also controlled the rusty plum aphid. None of the insecticides were effective against the gray sugarcane mealybug.

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[3] Analyses made by Pittsburgh Coke and Chemical Company, who furnished the Systox for the tests.

A Preliminary Investigation of Breakdown of DDT in Granulated Formulations[1, 2]

P. R. SFERRA, *Rutgers University, New Brunswick, N. J.*

Three 30–50 mesh granulated carriers, attapulgite, bentonite and tobacco, formulated to contain 10% DDT by weight, were chemically analyzed to determine their stability. Two different methods of formulation, solvent-impregnation and fusion, were employed. Tests were carried out on formulations supplied by a commercial firm and on formulations experimentally produced in the laboratory by the author.

METHODS.—Each formulation was sampled with a riffle and three 10-gram samples of each were extracted with 250 ml. of benzene on a shaker for 1 hour. From each extraction two samples were taken for Schechter-Haller analysis and two samples for total organic chlorine analysis (Anonymous 1955). In addition, unimpregnated granules were employed for blanks and 100% technical DDT was used for controls.

The Schechter-Haller colorimetric procedure provided a quantitative method of analysis for DDT and a qualitative test (a final pink color) for the presence of degradation products. The total organic chlorine represented the sum of DDT and its degradation products found in the formulations. The results of these analyses are shown in table 1. Two separate batches of each type of formulation were made at Rutgers University. Therefore the results obtained for each type of laboratory-prepared formulation are averages of replicates of two separate preparations. In addition, all laboratory-prepared formulations were processed with 10 grams of DDT per 90 grams of carrier. Total organic chlorine analyses run by the manufacturer immediately after the formulation of the commercial products range from 9.4% DDT in fused bentonite to 11.5% DDT in solvent-impregnated attapulgite. Thus, any formulation from which more than 100% recovery of DDT is reported contained more than the required 10% DDT by weight.

RESULTS.—The results indicate that the amount of breakdown of DDT varied considerably according to the method of formulation employed, the highest losses occurring in attapulgite formulations. When DDT was fused on attapulgite granules a very rapid breakdown occurred with a loss of at least 40% of the DDT. This occurred in laboratory prepared materials which were analyzed immeditely after formulation. The DDT fused on attapulgite produced commercially in December, 1954, exhibited the same phenomenon of rapid breakdown. On the other hand, DDT fused on bentonite (Rutgers formulations) apparently did not break down as much during formulation since it showed a loss of DDT amounting to approximately 20%. Fused commercial preparations of the attapulgite or bentonite type formulated in the spring of 1953 were found to contain less than half of their original DDT content. Unfortunately, these materials were not analyzed by the Schechter-Haller method immediately after they were formulated, thus the extent of breakdown of DDT due to aging could not be determined.

DDT fused on tobacco exhibited a negligible amount of breakdown. This was true also for all of the solvent-impregnated materials with the exception of the attapulgite, solvent-impregnated commercially, which was analyzed when 24 and 29 months old. The breakdown of the DDT exhibited by this material occurred probably with age.

It is apparent from these results that fused formulations are more unstable than solvent-impregnated ones and that compatibility varies according to the type of carrier used. Since greater immediate breakdown occurs in fused attapulgite than in fused bentonite or tobacco it appears that the heat (100 to

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[2] Investigations conducted under a grant from Diamond Black Leaf Company, Richmond, Virginia.

Table 1.—DDT recovery from granulated formulations.

Carrier	Source and Type of Formulation	Averaged Per Cent DDT Recovered: Schechter-Haller Analyses[a] Feb.-Mar. 1955	Schechter-Haller Analyses[a] July-Aug. 1955	Total Organic Chlorine Analyses[b] Feb.-Mar. 1955	Total Organic Chlorine Analyses[b] July-Aug. 1955
Attapulgite 30–50 mesh	Commercial fused[c]	46	38	90	85
	Commercial fused[d]	38	36	78	71
	Rutgers fused		63		91
	Commercial solvent-impregnated[c]	80	74	100	91
	Commercial solvent-impregnated[e]	102	104	100	97
	Rutgers solvent-impregnated		92		104
Bentonite 30–50 mesh	Commercial fused[c]		46		75
	Rutgers fused		82		96
	Rutgers solvent-impregnated		86		88
Tobacco 30–50 mesh	Commercial fused[c]		92		100
	Commercial solvent-impregnated[c]		110		102

[a] Standard deviation of controls (Schechter-Haller): 7.1%.
[b] Standard deviation of controls (Total organic chlorine): 6.4%.
[c] Formulated Spring, 1953.
[d] Formulated December, 1954.
[e] Formulated January, 1955.

104° C.) which is applied during the fusion process intensifies the incompatibility of attapulgite with DDT.

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Tests to Develop Nonexplosive Mixtures of Solvents in Formulations for Use in Aerosol Generators[1]

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To prevent explosions in buildings when using aerosols produced by generators, a formulation must be used which will not explode even if a spark or an open flame is present. A previous paper (Yeomans & Van Leeuwen 1954) showed that aerosols of fine particle size exploded more readily than those having larger particles. It was also found that tetrachloroethylene if present in sufficient quantity would suppress the flammable solvent, producing a nonexplosive formulation.

Laudani *et al.* (1954) tested a number of DDT-lindane formulations having a mixture of flammable solvents and tetrachloroethylene to determine their stability at low temperatures and their comparative toxicity to adult flour beetles. The results indicated that in most cases the formulations containing mixtures were more stable than those with tetrachloroethylene alone as the solvent. The biological tests showed that there was no toxicity difference between the formulations containing the flammable-nonflammable solvent mixtures and those containing tetrachloroethylene alone.

Since such mixtures would cost much less than tetrachloroethylene alone, the investigation was continued by determining the maximum quantity of a number of flammable solvents that could be mixed with tetrachloroethylene to produce nonexplosive formulations. A particle size much smaller than that used in the previous tests was selected to represent the lower end of the range occurring in generator-produced aerosols.

The tests were made with a modification of the Chemical Specialties Manufacturers Association drum test. The modifications included an oil burner sparking mechanism placed near the center of the drum and continually operated while the formulation was being introduced into the drum, and a dispensing mechanism. This consisted of a reservoir, a solenoid valve, a needle valve, and a ¼-inch diameter copper tube.

The formulation under test was released by the solenoid, and the flow rate from the reservoir was regulated by the needle valve. The copper tube directed the liquid into the back of the drum onto a cast iron pan heated to 850° F. with a 1000-watt electric heater. The formulation flowing onto this heated pan was volatilized into smoke-sized particles. When the concentration of the aerosol reached the explosive point, the spark ignited the mixture and blew the door of the drum open. If no explosion took place in 10 minutes with 200 ml. of the formulation in the closed drum and the spark operating, then the formulation was considered to be nonexplosive.

The following flammable solvents were evaluated in mixtures with tetrachloroethylene: Panasol AN-1, Panasol AN-3, Solvesso-100, Solvesso-150, Velsicol AR-50G, Velsicol AR-60, Sovacide 544C, Heavy Aromatic Naphtha 132, deodorized APCO 467 and MEK. The flash point of these solvents varied from 115° to 190° F. (COC). In some cases SAE-50 motor oil was also present in the formulations and each contained 10% DDT and 2% lindane. The formulations tested contained 29.3, 27.7, or 15.0% of the flammable solvents.

The results of the explosion tests are shown in table 1. All

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[2] John Olson, Jr. and Gerald Eason, of the Agricultural Marketing Service of the U. S. Department of Agriculture, assisted in making these tests.

Table 1.—Explosiveness of aerosol formulations containing various proportions of flammable solvents in a modified C.S.M.A. drum test.

Flammable Solvent: Name	Flammable Solvent: Per Cent in Formulation	Per Cent in Tetrachloroethylene in Formulation	Per Cent of SAE-50 Oil in Formulation	Volume (ml.) Introduced When Explosion Occurred[a]
Panasol AN-1	29.3	58.7	—	61
	27.7	55.3	5.0	68
	15.0	73.0	—	No explosion
Panasol AN-3	29.3	58.7	—	74
	27.7	55.3	5.0	66
	15.0	73.0	—	No explosion
Solvesso-100	27.7	55.3	5.0	18
	15.0	73.0	—	No explosion
Solvesso-150	29.3	58.7	—	21
	27.7	55.3	5.0	29
	15.0	73.0	—	No explosion
Velsicol AR-50G	29.3	58.7	—	69
	27.7	55.3	5.0	78
	15.0	73.0	—	No explosion
Velsicol AR-60	29.3	58.7	—	70
	27.7	55.3	5.0	68
	15.0	73.0	—	No explosion
Sovacide 544C	29.3	58.7	—	74
	27.7	55.3	5.0	82
	15.0	73.0	—	No explosion
Heavy Aromatic Naptha 132	29.3	58.7	—	104
	27.7	55.3	5.0	130
	15.0	73.0	—	No explosion
Deodorized APCO 467	15.0	73.0	—	102[b]
MEK	29.3	58.7	—	49
	27.7	55.3	5.0	20

[a] These volumes are averages of five replications.
[b] An explosion occurred in one replication, but not in four others.

mixtures containing 27.7% or more of flammable solvent exploded, but all but one containing 15% were nonexplosive.

The results of the tests show that the proportion of flammable solvents must fall somewhere between 27.7 and 15%, by formulation weight, to avoid the hazard of explosion. Since the tetrachloroethylene has a specific gravity of about 1.6, the percentage on a volume basis would be about double this amount. The use of flammable solvents such as those tested would reduce the formulation cost and yet give as good kill, as other tests have shown, as the previously recommended formula containing only tetrachloroethylene as the solvent.

The modifications of the C.S.M.A. drum as described appear to result in an accurate test that can be used to determine the explosiveness of aerosol formulations containing mixtures of flammable and nonflammable solvents.

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Aedes sollicitans in Illinois[1]

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The so-called salt-marsh mosquito, *Aedes sollicitans* (Wlk.), is limited in distribution in Illinois, but it is a pest at times and in certain places. The year, 1955, was one of those times, and extensive areas of southern Illinois were involved. Generally this species is found in a narrow crescent that extends from the southeastern part of the state north and west toward the Mississippi River thence north and east to Chicago. Within this range, actual sources are small acreages of transient water that are more or less numerous.

Larval sites in this state are conspicuously associated with waters that are impounded (1) near piles of mine or factory wastes, (2) near effluents from coal washers or (3) near oil wells. Specifically, prolific sources occur when water is temporarily ponded on these areas as a result of normal runoff following rains. Such areas are suitable oviposition sites during intervals of drying, and extensive areas for larval development are maintained during periods of overflow.

Typical sites for oviposition in most of the infested area have certain characteristics. Piles of rocky waste (called *gob piles*) from coal mines are most important. When piles of gob encroach onto land subject to alternate flooding and drying, suitable oviposition sites may be provided. In cases where gob piles are deep enough to maintain seepage areas at their bases, continuous oviposition sites are provided along the zone of drying. Temporary and relatively stationary flooding of such areas by runoff following rains provides suitable larval sites. Specific examples of known sites follow.

A larval site near West Frankfort occurs on the floodplain of a sluggish stream. An embayment has been formed by a highway fill that diverts the stream under a narrow bridge. A hundred yards or more downstream the embayment is bounded by an encroaching gob pile some 30 feet deep. The intermittent stream on the plain runs through a shallow ill-defined channel. Several times during the year it inundates the embayment. Between floods seepage from the gob pile wets the soil of the floodplain for a varying distance from the base of the pile. Eggs have been found in samples taken from grassy hummocks and patches of grass in a zone several rods from the base of the pile. Eggs were absent from samples adjacent to the base of the pile and from areas far removed from it. Eggs of both *Aedes stimulans* (Wlk.) and *A. vexans* (Meig.) were found with *A. sollicitans*.

One site for *A. sollicitans* was found that was created during early summer of 1955. It is a shallow ponded area created where a road fill made from gob obstructed the flow of runoff water. Following rains, seepage from the fill and runoff from the roadside ditch collects in the impounded area. Runoff from the watershed filled the area following rains. Eggs were numerous in samples taken from soil shaded by barnyard grass in a zone about 100 yards from the road. Eggs associated with *A. sollicitans* in this site were *A. sticticus* (Meig.), *A. vexans* and even a few *A. canadensis* (Theob.). Embryos in eggs of the latter species were dead thus indicating that these eggs had been deposited prior to construction of the fill, and the new environment was toxic.

A site of great abundance of *A. sollicitans* was created in Saline County, Illinois in a vast cattail marsh that was bounded on all sides by prominent hills. Within recent years effluents from coal washers have deposited a delta of fine red silt over some 25 or more acres to a depth of 3 or more feet in places. Even more recently a channel bounded by levees has been dug across the delta to carry the waste from one washer farther out on to the marsh. At the mouth of the channel a silt dam has formed. As a consequence the water is turned to flow backward over the old delta so that part of the delta as well as several acres of pasture land above it are periodically flooded. Water from this channel flows over its floodplain only when the washer is operating. The soil has an opportunity to dry between periods of flooding. Eggs have been found in profusion at certain points on the old delta and in the grassy land above it. One low hummock of barnyard grass, *Echinochloa crus-galli*, yielded upwards of 4000 eggs of *Aedes sollicitans* per square foot without other species. Another similar site, but one with more debris on the surface, yielded upwards of 20,000 eggs per square foot. The area of highest yield was a clump of dead barnyard grass which bore a pure population of 10,733 eggs of *A. sollicitans* on an area measuring 6 inches square. Elsewhere eggs were abundant in clumps of smartweed and bunch grasses above the delta wherever the mine waste covered the soil. At these horizons mixed populations of *Psorophora confinnis* (L.-Arr.), *A. vexans* and even *P. ciliata* (Fabr.) were found.

All of the known oviposition sites for *A. sollicitans* found in Illinois have sulphur in some form in the soil. The soil has a sulfurous odor detectable by the human nose. The sulphur appears in the oviposition sites as sulphites in the effluents from mines. In some manner the sulphites are converted to other forms and an odor is apparent. Sodium or other chlorides are either absent or of a low order in the water. The larvae are found in fresh water where they thrive.

The form of *Aedes sollicitans* present in Illinois is apparently the same as that of coastal areas. Certainly the eggs are identical as will be shown in a later paper.

SUMMARY.—*Aedes sollicitans* in Illinois is limited in its distribution to areas where solutes in wastes from coal mines, certain factories or oil wells collect in soil subject to transient flooding. The most universal feature of oviposition sites is a sulphurous odor to the soil. Eggs of this species are typically found as a pure population. At higher horizons they are sometimes found with *A. stimulans*, *A. vexans*, *Psorophora confinis* and *P. ciliata*. Larvae develop in non-saline waters.

[1] Contribution from the Department of Entomology, University of Illinois. Funds for support of the investigation were provided by the U. S. Public Health Service. Accepted for publication March 30, 1956.

Drosophila as a Pest of Canning Tomatoes[1]

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Flies of the genus *Drosophila*, primarily *melanogaster*, present a serious problem in the processing of tomatoes because eggs deposited on fruit may reach the can and be considered contaminants. Reports on various aspects of the problem have been given by Bickley & Ditman (1954), Michelbacher & Middlekauff (1954), and Pepper *et al.* (1953). Investigations conducted in Maryland in 1954 and 1955 are discussed in this paper.

POPULATION ESTIMATES.—Various methods may be used to obtain indices of the abundance of adults or eggs. Michelbacher & Middlekauff (1954) have preferred to make a vertical slit of about 1.5 inches in a ripe tomato and count the eggs under a binocular stereoscopic microscope after the sample tomatoes have been exposed under tomato plants or other places for a given period of time.

Jar traps have been used in Maryland to estimate adult densities. Half of a nearly ripe tomato is placed in a fruit jar with a paper funnel at the mouth. A hole about half the diameter of an ordinary lead pencil allows flies to enter the jar through the funnel. Adults are chloroformed and counted after appropriate intervals. Jar traps have been placed in fields and at factories for purposes of comparison.

Another method of determining the extent of infestation consists of examining under a stereoscopic microscope tomatoes from different parts of fields as they are picked to be sent to the factory. Samples of 100 tomatoes are selected and eggs present are counted. Records of the number of growth cracks and the number of tomatoes mechanically damaged are obtained. A few eggs are deposited on perfect fruit, usually near the stem. Many eggs are found in normal growth cracks; and greatest numbers are usually found at places where the skin is broken in handling.

A simple method found to be reliable for making egg counts is based on the exposure of 1 square inch of tomato flesh. Shallow slits are made to mark off the square inch and the skin is peeled off. A little pressure to the exposed area with a knife brings more moisture to the surface and presumably makes the spot attractive for a long period of time to ovipositing *Drosophila*. Eggs are deposited on the surface rather than deep in slits so that they may be counted with a hand lens. The elimination of a microscope simplifies the procedure. Sample tomatoes are placed in small hardware cloth cages to preclude damage by turtles, mice, or other pests.

In 1954 comparisons of counts by the various methods gave convincing evidence that all of them revealed seasonal fluctuations in populations in about the same proportions. Counts of the number of eggs per square inch of exposed flesh were adopted for subsequent work. A high egg count on a few tomatoes is of greater interest to processors than a high percentage of infested tomatoes because the latter figure may actually be based on a small number of eggs. As a result of thorough field surveys in 1954 and 1955 further weight was added to support the conclusion that multiplication of *Drosophila* takes place for the most part in tomato fields.

SPRAYING HARVESTED TOMATOES.—In the fall of 1954, small-scale experiments were conducted to determine whether oviposition could be reduced by spraying baskets of tomatoes with malathion and Dilan. The baskets were filled with ripe canning tomatoes, some of which were prepared with eye slits and distributed throughout the bottom, middle, and top of the baskets. Eggs were counted after 24 hours in the prepared slits. The treatments consisted of 55% malathion emulsion diluted 1:100 and 25% Dilan emulsion diluted 2:100. Approximately 1 gallon of finished spray was applied to 10 baskets. Results indicated that oviposition was materially reduced with these sprays, Dilan being slightly superior.

Similar treatments were given a second group of tomatoes in baskets. These tomatoes were canned, keeping the top and bottom tomatoes separate. Whole tomatoes and tomato juice from these fruits were processed and submitted to taste panelists. No off-flavor resulted from either bottom or top tomatoes from either insecticide.

Anticipating possible future contamination of the processed product a study was also made of the malathion breakdown in canned tomatoes. Malathion at the rate of 20 and 40 p.p.m. was incorporated into cans of whole tomatoes for analysis.[2] After 1 week, nearly as much malathion remained as was originally put into the cans. This is indicative that if malathion residues were to remain on the tomatoes when processed, they would persist for some time. The normal treatment of tomatoes for canning, however, requires washing and peeling. If any residues should persist, these would therefore be expected to be small.

In 1955 an experiment was carried out to discover the effect of pyrethrum sprays on oviposition. This experiment was suggested by members of the Committee on Tomato Products Sanitation of the National Canners Association. Pyrethrum sprays are recommended for application to tomatoes at various points from field to processing, and although it is known that many adults are killed, there has been no precise information available to show that these applications reduce the number of eggs.

On September 12 near Westminster, Maryland in the afternoon when the oviposition rate in the field was very high a pyrethrum spray was applied to baskets of tomatoes as they were being loaded into a truck. Each layer of baskets was thoroughly drenched from all sides so that most of the individual tomatoes received some of the material. About 25 gallons of spray material were used with a garden hose nozzle at a pressure of about 200 p.s.i. The mixture consisted of approximately 0.075% technical piperonyl butoxide and 0.0075% pyrethrins in water.[3] The truck was moved at once to the factory a few miles away and unloaded about 5:30 p.m. These tomatoes were the only ones remaining at the factory overnight.

Prior to application of the spray, 10 egg-free tomatoes with a square inch of flesh exposed were placed in marked baskets just as the baskets were being loaded in the truck. These marked baskets were placed at random in various positions on the truck. After the truck was unloaded, all baskets except five of the marked ones were sprayed a second time with an oil-pyrethrum mixture using an electric atomizing sprayer, a routine procedure at many canneries. Five tomatoes with a square inch of flesh exposed were used as a check. These were placed in marked baskets in a second field and left in the field overnight. Conditions in the two fields were similar except that no spraying was done in the second field.

Counts of the number of eggs were made about 17 hours after treatment, as the check baskets were unloaded on the morning of September 13. Of the five tomatoes from baskets that were sprayed once in the field, two were infested with a total of 12 eggs; of the five tomatoes that were from baskets sprayed both in the field and at the factory, one was infested with two eggs; all five of the check tomatoes were infested with an estimated total of 3500 eggs. From these results it may be concluded that pyrethrum sprays applied to baskets of tomatoes as they are loaded into trucks in fields will reduce oviposition by *Drosophila*. Sprays applied at this time have a greater effect on the number of eggs than sprays applied at factories. Such sprays kill most of the adults on trucks and stop the movement of large numbers of adults from field to canning plants. It appears that most of the adults at factories are brought directly from fields.

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[2] Credit is extended to Dr. Paul A. Giang of the Entomology Research Branch, Agricultural Research Service, U. S. Department of Agriculture for the chemical residue analysis.

[3] ½ pint "Pyrenone-606" in 50 gallons of water.

FIELD SPRAYING.—In 1954 two fields each comprising about 3 acres were sprayed with malathion. On August 25 the application consisted of 2 pints 50% emulsifiable concentrate in 40 gallons of water per acre. On September 8 spraying was at the rate of 2 pints of 50% emulsion concentrate in 10 gallons of water per acre using a weed boom. These applications had no appreciable effect in reducing the number of eggs found on fruit in fields. Because these treatments were ineffective the data on populations are not given. Egg counts per square inch of exposed flesh ranged from 250 to 1000 before and after treatments and also in a nearby unsprayed field. It was ascertained that the malathion applications as described did not affect the flavor of tomatoes which were harvested and canned immediately after spraying or 2 and 5 days later. Residue analyses were negative.

In 1955 some small scale investigations were made on malathion sprays with and without the addition of tomato juice, and/or sugar, and/or Staley's Sauce Base No. 2 (partially hydrolyzed yeast protein). On the whole the results were inconclusive. Additional experiments with yeast are planned.

REPELLENTS.—Observations on numerous occasions have shown that pyrethrum sprays have little or no repellent action. When a spray has been applied to a basket of tomatoes with many *Drosophila* adults on it, some of the gnats are killed on contact, but many are driven off. Almost immediately after a basket has been sprayed swarms of gnats settle down again on it.

Some small scale experiments in 1955 showed that butoxy polypropylene glycol was effective in repelling *Drosophila* adults. Baskets of tomatoes were sprayed with a mixture of 1 pint in 9 pints of water, and egg counts were made 18 hours later. The number of eggs per square inch of exposed flesh averaged only one on sprayed tomatoes in contrast to 1000 on unsprayed fruit. It is possible that a lower concentration will be effective.

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Flies Associated with Tomatoes in Maryland[1]

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The presence of *Drosophila* eggs on tomatoes destined for canning has plagued the industry for several years, and the problem is particularly vexing because most oviposition occurs in tomato fields where adult populations reach tremendous heights and no practical control methods have been discovered. Some observations on various species of *Drosophila* and other flies in Maryland fields were reported by Bickley & Ditman (1954) and Harrison *et al.* (1954). This is a report on the species of *Drosophila* and other flies collected at tomato processing plants and in tomato fields. Observations on the biology of various species should be of interest because different species probably vary in their reactions to insecticides, attractants, and repellents.

Sufficient collecting in six Maryland counties has been done to prove conclusively that *D. melanogaster* Meigen is much more abundant than other species in tomato fields and at processing plants. It occurs throughout the period when tomatoes are ripening, and swarms are usually seen in tomato fields from the middle of August until frost. This species predominates until the advent of cool weather in October when it is usually outnumbered by *D. hydei* Sturt. and sometimes by *D. funebris* Fab. For the entire tomato harvesting period it is estimated that *D. melanogaster* constitutes at least 95% of the *Drosophila* associated with tomatoes. An annotated list of the other species follows:

1.—*D. hydei* Sturt. occurs throughout August, September, and October. It appears to multiply rapidly with the onset of cool weather. According to Patterson & Wagner (1943) this is the second most common species of *Drosophila* in the United States. This seems to hold for Maryland. *D. hydei* is larger than *D. melanogsater* (female body length, 3.4 mm. and 2 mm., respectively). It is very dark, giving the appearance of being black. The eggs have four tapering filaments. This species has been reared from field collected tomatoes, and is easily cultured on tomatoes in the laboratory. In some cases there were indications that *D. hydei* was slightly less susceptible to pyrethrum sprays than *D. melanogaster*.

2.—*D. tripunctata* Loew is another species that is found more often later in the season. It superficially resembles *D. melanogaster* very closely. The length of the body is 2.5 mm. (Patterson 1943). The eggs have four filaments. This species is considered the third most common one associated with tomatoes in Maryland. It has been reared from field-collected tomatoes.

3.—*D. affinis* Sturt. is ranked fourth in abundance on tomatoes in Maryland and occurs with *D. melanogaster* from early in August until frost. It is very similar to *D. malanogaster* in size and general appearance, but the abdominal segments dorsally are almost entirely dark brown. Eggs resemble very closely those of *D. melanogaster*.

4—*D. immigrans* Sturt. is listed next not because it was very abundant but because it is known to oviposit on tomatoes, having been reared from fruit collected in fields. It is very similar to *D. melanogaster* in general appearance, but is slightly larger. The eggs have four tapering filaments.

5.—*D. funebris* Fab. occurs late in the season along with *D. hydei*. Larvae develop readily in tomatoes. This species has a body length of 2.5 mm., and it is much darker than *D. melanogaster* but not so dark as *D. hydei*. The eggs have four tapering filaments.

6.—*D. algonquin* Sturt. and Dob. is closely related to *D. affinis*. It is slightly larger and more brownish than *D. affinis* or *D. melanogaster*. It was collected only in late September and has not been found on the Eastern Shore. Adults are attracted to tomatoes, but no evidence that larvae develop in tomatoes has been obtained.

7.—*D. transversa* Fallen occurs late in the season, and whether or not it breeds naturally in tomatoes has not been ascertained. This species is about the same size as *D. melanogaster*, but it is lighter in color with dorsal abdominal spots instead of bands. The egg has three filaments.

8.—*D. quinaria* Loew, a close relative of *D. transversa*, has been collected only once—in a tomato field near Goldsboro, September 9, 1953. It is a little larger than *D. transversa*, and the abdominal spots are more prominent.

9.—*D. busckii* Coq. is a yellowish species about the same size as *D. melanogaster* but characterized by dark longitudinal stripes on the mesonotum. It was encountered only once during the course of these studies, in a tomato field at Fairland, Md., August 23, 1952.

10.—*D. repleta* Wollaston appeared to be fairly common in earlier investigations in Maryland (Ditman *et al.* 1936) but has

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Dr. Willis W. Wirth, Entomology Research Branch, U. S. Department of Agriculture, determined or assisted in the determination of specimens of the family Drosophilidae and certain other families. Dr. Curtis W. Sabrosky, Entomology Research Branch, determined specimens of the families Musicidae, Chloropidae and others. Their assistance is gratefully acknowledged. Acknowledgment is also made of the assistance of Messrs. H. L. Dozier and Ellis G. MacLeod in certain phases of the work.

not been observed in recent years. *D. hydei* is the dominant member of the *repleta* group in Maryland.

11.—*Parascaptomyza disticha* Duda (=*Scaptomyza graminum* of authors) was reared from eggs that had been deposited on sound tomatoes. This species is a member of the family Drosophilidae and resembles *Drosophila*.

OTHER SPECIES.—Many different kinds of dipterous eggs are found in normal growth cracks of tomatoes and around the stem end. It has been observed that very few larvae hatch and develop, excluding Drosophilidae. Unlike *Drosophila* most other fly eggs are not imbedded in or cemented to tomato flesh. In addition to the Drosophilids discussed only two flies have been reared from tomatoes in Maryland. These were *Musca domestica* L. and *Muscina assimilis* Fallen. The latter species oviposits very frequently on tomatoes before they are picked. Both species are produced in rotting tomatoes so that large populations are seen in fields. Of course, many other scavenger flies breed in decomposing tomatoes, but they probably never deposit eggs on sound fruit.

Collections of flies that frequently alight on tomatoes in fields have been made with an aspirator or chloroform tube. It is possible that some of these flies have deposited eggs which have not been identified.

There is circumstantial evidence that *Oscinella* spp. and other chloropids frequently oviposit on tomatoes. In addition to *Drosophila* spp. the following flies are commonly seen on tomatoes in Maryland fields:

Heleidae: *Atrichopogon levis* (Coq.)
Sepsidae: *Sepsis* sp.
Opomyzidae: *Anrhomyza* sp.
Drosophilidae: *Parascaptomyza disticha* Duda and *Scaptomyza adusta* (Loew).
Chloropidae: *Oscinella carbonaria* (Loew)., *O. coxendix* (Fitch), *Hippelates dissidens* (Tuck)., *H. bishoppi* Sabr., *H. particeps* (Beck). *H. plebejus* Loew.
Sphaeroceridae: *Leptocera frontinalis* (Fallen).
Muscidae: *Muscina assimilis* Fallen, *Musca domestica* L.

A culture of *Drosophila melanogaster* developing in a field-collected tomato yielded 10 specimens belonging to the genus *Aspilota* (Hymenoptera: Braconidae). Mr. C. F. W. Muesebeck made the determination and stated that species of this genus have not been thoroughly studied. These parasites are probably indiscriminate in their choice of small flies as hosts.

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Effectiveness Against House Flies of Some 3,4-Methylenedioxyphenoxy Compounds as Synergists for Pyrethrins and Allethrin[1,2]

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Recently in a paper describing the synthesis of 3,4-methylenedioxyphenoxy compounds, Beroza (1956) reviewed briefly the synergist problem leading up to the discovery of the intensely synergistic properties of sesamolin (Beroza 1954), which is found in sesame oil in addition to sesamin.

Sesamolin, which has been shown to be about five times as synergistic as sesamin against the house fly (Gersdorff *et al.* 1954), differs from sesamin in containing a 3,4-methylenedioxyphenoxy group in place of one of the 3,4-methylenedioxyphenyl groups (Beroza 1954, 1955). This work led to the preparation by Beroza of 3,4-methylenedioxyphenoxy derivatives, and Gersdorff *et al.* (1956) tested 63 of them as synergists for both pyrethrins and allethrin by the turntable method. These new materials were acetals, ethers, esters, sulfonates, and urethans. Some of these compounds caused high synergism with either of these insecticides. Because results by the turntable and Peet-Grady methods sometimes give different results and because the latter method gives a better idea of synergism as related to knockdown, certain of these compounds were examined by the Peet-Grady procedure. This paper reports these results.

MATERIAL.—Seven of the materials from among the 43 that Gersdorff had found to demonstrate synergism with both pyrethrins and allethrin were selected for these tests. They included three acetals, one ether, one benzenesulfonate, one furan, and one dioxane derivative. The test solutions contained 0.4 mg. of the insecticide plus 2 mg. of the synergist per milliliter of kerosene. To keep the synergist in solution, 7.5% and 5% of acetone were included in the sprays containing the benzenesulfonate and dioxane derivatives, respectively. The samples were run in four series, two each with pyrethrins and allethrin. With each series the pyrethrins or allethrin was tested at concentrations of 0.4, 0.8, and 1.6 mg. per milliliter, and the synergist piperonyl butoxide (99.5%) was also tried at the same concentration as the compounds under test. Each series of tests was run at a different time and replicated three times by the small-group method.

RESULTS.—The results, given in table 1, show the knockdown in 5 and 10 minutes and the mortality in 1 day. The allethrin sprays gave a generally lower level of performance than the pyrethrins sprays.

The 2-(2-ethoxyethoxy)ethyl 3,4-methylenedioxyphenyl acetal of acetaldehyde was the best material tried with both pyrethrins and allethrin. The 2-(2-butoxyethoxy)ethyl 3,4-methylenedioxyphenyl acetal of acetaldehyde was equal to it with pyrethrins but with allethrin was much less effective in mortality. The 2-(2-butoxyethoxy)ethyl 3,4-methylenedioxyphenyl ether and the 2-butoxyethyl 3,4-methylenedioxyphenyl acetal of acetaldehyde were slightly more effective than piperonyl butoxide with both insecticides.

The other three synergists gave results that were well under the performance of piperonyl butoxide in the pyrethrins series, but with allethrin two of them were about as effective.

2-(3,4-Methylenedioxyphenoxy)tetrahydropyran, which Gersdorff showed to exhibit synergism, was tried in one of the pyrethrins series. It caused 60% knockdown in 5 minutes, 74% in 10 minutes, and a kill of only 10%.

DISCUSSION.—This work shows that, of eight synthetic compounds containing the 3,4-methylenedioxyphenoxy group that

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[2] Presented at the Eastern Branch Meeting of Entomological Society of America at Baltimore, Md., November 21–22, 1955.

Table 1.—Results of house fly tests with 3,4-methylenedioxyphenoxy compounds as synergists with pyrethrins and allethrin.[a]

Synergist (2 Mg./Ml.)	Pyrethrins (0.4 Mg./Ml.)			Allethrin (0.4 Mg./Ml.)		
	Per Cent Knockdown in—		Per Cent Kill in 1 Day	Per Cent Knockdown in—		Per Cent Kill in 1 Day
	5 Minutes	10 Minutes		5 Minutes	10 Minutes	
	Series I			*Series II*		
Acetaldehyde, 2-(2-ethoxyethoxy)ethyl 3,4-methylenedioxyphenyl acetal	89	99	90	59	86	68
Acetaldehyde, 2-butoxyethyl 3,4-methylenedioxyphenyl acetal	77	92	76	53	90	63
Ether, 2-(2-butoxyethoxy)ethyl 3,4-methylenedioxyphenyl	89	97	82	58	87	59
Furan, tetrahydro-, 2-ethoxy-5-(3,4-methylenedioxyphenoxy)-	62	82	18	55	86	49
Piperonyl butoxide	86	94	72	62	81	56
Insecticide (no synergist):						
0.4 mg./ml.	61	65	4	48	79	14
0.8 mg./ml.	79	90	10	77	92	34
1.6 mg./ml.	90	99	37	88	96	68
	Series III			*Series IV*		
Acetaldehyde, 2-(2-butoxyethoxy)ethyl 3,4-methylenedioxyphenyl acetal	87	95	89	63	84	39
Benzenesulfonic acid, 3,4-methylenedioxyphenyl ester	70	87	22	63	86	49
p-Dioxane, 2-(3,4-methylenedioxyphenoxy)-	72	82	10	50	75	28
Piperonyl butoxide	86	97	76	59	84	46
Insecticide (no synergist):						
0.4 mg./ml.	58	75	3	37	63	5
0.8 mg./ml.	92	95	6	78	91	27
1.6 mg./ml.	96	99	24	90	97	57

[a] Average of 3 tests.

had previously shown a high degree of synergism by the turntable method, four showed it by the Peet-Grady procedure with both pyrethrins and allethrin. Each of these compounds appears to be equal to or better than piperonyl butoxide as a synergist.

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Polyhedrosis Wilt of Cabbage Looper on Long Island[1]

Maurie Semel, *Long Island Vegetable Research Farm, Riverhead, N. Y.*

The cabbage looper, *Trichoplusia ni* (Hbn.), has been of increasing concern since 1953 to growers of cruciferous crops on Long Island apparently due to its increased resistance to DDT. The presence of an extremely heavy, first-generation moth population in the early summer of 1955 signaled extreme difficulty because of this pest.

It was during the course of a series of cabbage worm control investigations to find more effective insecticides that the author observed a large number of moribund larvae of the second-generation cabbage loopers in the field test plots. The date of first observation was August 15 at which time many larvae appeared dull, pale yellow. Microscopic examination of extracted body fluid at a magnification of 900× revealed countless refractive particles, but the exact nature and shape of the crystal-like bodies could not be resolved.

The significance of the disease was soon brought to the writer's attention by a large number of growers who reported that they had found effective means of combating the looper menace. Without exception, each of the cases was a vivid portrayal of the virulence of the pathogen in decimating a looper population.

Specimens sent to Dr. Edward A. Steinhaus[2] were found to be infected with a polyhedral virus. This is the first positive identification of the causal agent of the disease of cabbage looper in New York State. It appears, however, that Sirrine (1894) was the first to describe the symptoms of this disease and its im-

[1] Accepted for publication February 28, 1956.

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portance in keeping in check the high population of cabbage looper on Long Island. In that year the first diseased specimens were not noticed until October 27. Huckett (1940) noted that the looper may be reduced to a position of little economic importance because of disease incidence. Without doubt, the polyhedrosis virus was here involved as it was in 1955 when the effectiveness of this disease was manifest by an epizootic which occurred in mid-September on Long Island and later in Western New York.

Apparently the disease may be found wherever there is a looper population although not always reaching epizootic proportions. Probably the first mention of the disease in the United States was made by Osborn (1893) who noted the importance of this factor in checking a severe outbreak of the looper in Iowa in 1892. Chittenden (1902) and workers in Ohio (Anonymous 1923) considered the disease of bacterial origin although, from the description given by the former, it appears to have been the virus disease. Many workers realized the value of the disease as a check on cabbage looper build-up although not always crediting a polyhedral virus as the causal agent. Among these were Chittenden (1909) and Walker & Anderson (1936) in Virginia, and Dills & Odland (1950) in Pennsylvania.

Chapman & Glaser (1915) were probably the first to find that polyhedral bodies were present in a diseased cabbage looper larva. The source of their infected specimen is uncertain. Hayslip *et al.* (1953) correctly identified the cause of disease outbreaks in Florida, and asserted the polyhedrosis virus "to be the greatest single factor in the late-season disappearance of cabbage loopers in the Everglades." At present, Dr. Irvin M. Hall in California is doing considerable work in attempting to control the cabbage looper with spray applications of polyhedral-body suspensions. (Steinhaus 1955).

As in the case of many other virus diseases of insects, the infected larvae behaved in a characteristic manner. The caterpillars invariably crawled to the outermost edges of the leaves of the foodplant where they became rather inactive. During this time body coloration changed from a shiny green to a dull, pale yellow and the amount of feeding was sharply reduced. The larvae soon died. The period of time from inactivation to death varied from approximately 1 to 6 days and appeared dependent on temperature, the higher temperatures apparently being more conducive to a more rapid demise. During the final stages of moribundity, the caterpillars released their hold with their true legs and hung limp from the plant by means of their prolegs. Soon the body turned chocolate-brown to blackish, the skin usually ruptured and the body contents, which had liquefied and darkened, oozed out and ran down over the plant surface.

Apparently the last larval stadia were more susceptible to the disease because only rarely were infected first and second instar larvae found. This may indicate also that a period of virus multiplication is necessary before the larvae succumb.

All attempts to hold apparently healthy larvae for laboratory tests of control insecticides were unsuccessful because of interference from the disease. Repeated efforts to inoculate the imported cabbageworm, *Pieris rapae* (L.) and the yellow-striped armyworm, *Prodenia ornithogalli* Guen. with the virus, either by oral or contact means, were without success. This seems to indicate that the pathogen may be specific to the cabbage looper.

It is encouraging to note the effectiveness of the polyhedral virus in all but completely arresting an epidemic of cabbage looper and it may be that biological control of this species by artificial dissemination of the virus may soon be realized.

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A Lightweight Cage for Leaf Feeding Insects[1]

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Small leaf cages, involving the principle of the leaf supporting the cage, have been widely used in insect biology studies and plant virus transmission investigations (Connel & Beacher 1947, Maramorosch 1951). Physical characteristics of such cages include light weight and relative noninterference with the physiology of the leaf.

The cage described below (Fig. 1) has found use with a grape

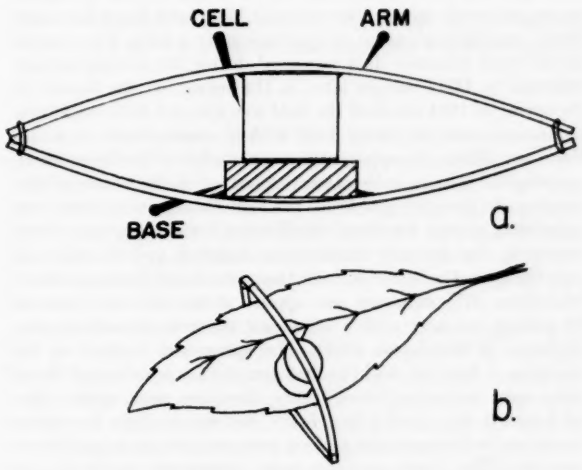

FIG. 1.—Leaf cage. a. Front view, showing component parts; b. Attachment to leaf.

leafhopper, *Erythroneura variabilis* Beamer, and the cottony-cushion scale, *Icerya purchasi* Mask. One advantage of this cage, other than its very light weight, is that it can be attached to almost any place on a leaf surface without damaging the leaf.

[1] Accepted for publication March 2, 1956.

The cell of the cage is made of a cellulose acetate strip with the ends cemented together. Lumite[2] screening covers the top of the cell and is attached with cellulose acetate cement. The base is made from pressed cork or balsa wood. Bamboo strips are attached with cellulose acetate cement at the edges of the cell and base; the notched ends of the bamboo arms are tied together with carpet thread. The tension of the arms, and the resulting pressure of the base and cell against the leaf, may be lessened by shaving the bamboo strips thinner and/or tying the arms together more loosely.

The cage is affixed to a leaf by grasping the arms of the cage between the thumb and forefinger and gripping gently. When the cell and base of the cage are slightly apart, the leaf is inserted and pressure on the arms is released.

A more durable and heavier cage may be made by using cut sections of glass tubing for the cell and spring steel for the arms of the cage. Nylon netting may be used for the top of the cell in place of the heavier Lumite screening. Maramorosch (1951) suggests using cellulose nitrate in leaf cages because of the toxic effect on plants of cellulose acetate.

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[2] Chicopee Mfg. Corp.

Residues and Flavors of Asparagus Treated with Malathion[1]

L. P. Ditman, Robert C. Wiley, and Paul A. Giang[2]

It has been the responsibility of the senior author to control asparagus beetle on the University of Maryland Plant Research Farm asparagus planting of approximately 1 acre. For a number of years rotenone dust was used during the cutting period, followed by DDT sprays later in the season on the brush. In the spring of 1954 one-half the field was sprayed with malathion (emulsion) and the other half with a combination of malathion and Dilan. An apparently complete kill of beetle resulted, so complete that no infestation reappeared in the brush by late summer. In the spring of 1955, the field was again sprayed with malathion, except for three check rows, for the purpose of determining the amount of malathion residues and the effect of malathion on the flavor of both the canned and frozen product. Malathion 57% emulsion was applied at the rate of 2 pints in 25 gallons per acre with a broadcast sprayer as used for peas (Ditman & Burkhardt 1952). The spray was applied on the morning of May 16, and the first samples for residue and flavor tests were harvested immediately. Samples were again taken 24 hours, 3 days, and 7 days later. Residue analysis was determined on fresh asparagus and on processed, canned, and frozen samples. The fresh samples were chemically analysed immediately after harvest, the processed samples on May 24, the flavor evaluations were made on November 23. The results of residue analysis by Norris colorimetric method (Norris *et al.* 1954) and of flavor evaluation by the multiple comparison method are given in table 1.

The immediate residue deposits resulting from the spray application were under the present tolerance of 8 p.p.m., and no malathion could be detected on fresh asparagus 3 days after treatment. All malathion was removed in processing both canned and frozen spears. No objectionable off-flavor was present in any processed samples there being no significant differences at the 1% point (T-test for paired comparison).

Table 1.—Results of malathion analysis and flavor evaluation on asparagus from time of treatment until 7 days after treatment.

Date Harvested		Malathion p.p.m.			Flavor Rating[a]	
		Fresh	Frozen	Canned	Frozen	Canned
May 16	Check	.0	—	—	+1.4	+ .50
	Treated	4.94	.0	.0	+ .64	+ .78
17	Check	0.0	.0	.0	+ .79	+1.07
	Treated	trace	.0	.0	+1.28	+ .71
19	Check	0.0	.0	.0	.0	+1.21
	Treated	0.0	.0	.0	+1.07	+ .86
23	Check	0.0	.0	.0	+1.71	+ .78
	Treated	0.0	.0	.0	+1.36	+1.00

[a] Samples scored as follows: +2 entirely acceptable, +1 acceptable, 0 borderline, −1 off-flavor, and −2 decidedly off-flavor.

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[1] Scientific Article No. A531, Contribution No. 2666, of the Maryland Agricultural Experiment Station, Department of Entomology. Accepted for publication March 6, 1956.

[2] L. P. Ditman, Research Professor, Department of Entomology, Robert C. Wiley, Assistant Professor, Department of Horticulture, both of the University of Maryland, and Paul A. Giang, Entomology Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

Eggplant Lace Bug and Harlequin Bug Susceptibility to Some Standard Insecticide Dust Formulations[1]

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The eggplant lace bug, *Gargaphia solani* Heid., is one of the most important pests on eggplant in North Carolina. For many years DDT has been used as a general insecticide to control this and other insects attacking the crop. More recently a number of very good materials have become widely used on truck crops and it was decided to compare the effectiveness of some of these against the lace bug.

Tests were made by placing 50 adult bugs in a half-gallon fruit jar. A 50-milligram puff of dust was discharged into the jar. Within 10 minutes the insects were transferred to another jar containing fresh eggplant leaves. The number of dead insects were counted at the end of 4, 8, 24, and 48 hours. Each treatment was replicated twice in this manner and the data graphed as shown in figure 1.

Harlequin bug (*Murgantia histrionica* (Hahn)) adults and last instar nymphs were tested in the same manner on collards, with a few insecticides. This technique has been used many times on a number of economic insects and has shown good correlation with field data.

Results.—An examination of figure 1 shows 20% sabadilla to have the greatest amount of insecticidal activity from the standpoint of velocity-mortality. All of the lace bugs were dead at the end of 4 hours. This material killed all of the harlequin bugs by the end of 8 hours.

[1] Contribution from the Entomology Department, North Carolina Agricultural Experiment Station. Accepted for publication March 15, 1956.

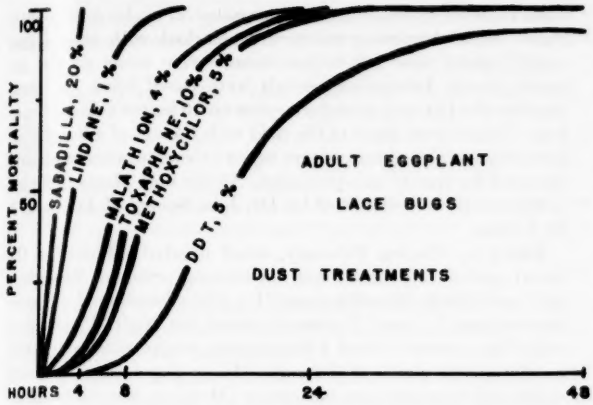

FIG. 1.—Velocity-mortality curves comparing the insecticidal activity of some standard insecticide dust formulations on adult eggplant lace bugs within a temperature range of 82° F. to 86° F.

The next most active material was 1% lindane. This was not tested against the harlequin bug. Four per cent malathion dust killed all of the lace bugs and harlequin bugs by the end of 24 hours.

Ten per cent toxaphene, 5% Perthane (not shown on the graph) and 5% methoxychlor were decreasingly active in this order in the lace bug test. Most of the insects were dead by the end of 24 hours. However, in the Perthane and methoxychlor treatments about 2% to 3% were still alive after 48 hours. Toxaphene was the only one of these materials tested on harlequin bugs. None of these insects were dead at the end of 8 hours and only 64% of them were dead after 48 hours.

Five per cent DDT was the slowest acting material on lace bugs. Eight per cent of the bugs were still alive after 48 hours. This material was not tested on harlequin bugs.

Ecological Studies of Thrips Found on Cotton in Central Texas[1]

B. G. HIGHTOWER and DIAL F. MARTIN,[2] *Texas Agricultural Experiment Station, College Station*

Thrips frequently develop heavy populations on seedling cotton in Central Texas. Damage from these infestations result in slow growth and malformed plants. According to Gaines (1934), *Frankliniella tritici* (Fitch) (flower thrips) and *F. fusca* (Hinds) (tobacco thrips) are the species responsible for much of this damage in this area. During 1954 and 1955 surveys were conducted near College Station to obtain information on the principal host plants and the dispersion of thrips to cotton.

EXPERIMENTAL PROCEDURE.—Tanglefoot traps were used in the dispersion studies. Each trap consisted of a 1-foot length of stove pipe, 7 inches in diameter, fixed on a wooden stake. A 5″×20″ strip of transparent plastic was coated with a thin layer of commercial Tanglefoot and fastened around the stove pipe with two large paper clamps. These traps were placed at a height of 18 inches above the ground among the spring host plants and 48 inches above the ground in the cotton fields. At weekly intervals the strips were removed and the thrips were counted and recorded. Samples of thrips were removed from the strips with a scalpel, passed through a 1:1 solution of absolute alcohol and carbon tetrachloride to remove the Tanglefoot, and preserved in 70% alcohol. These specimens were later mounted on slides for detailed taxonomic studies.

In the studies of thrips populations on cotton, 20 plants were collected at weekly intervals from each field under study. Collections were begun when the cotton had emerged to a stand and complete plants were collected at weekly intervals for 5 to 6 weeks. On cotton older than 6 weeks, it was necessary to reduce the sample to 10 terminals and 10 fruiting arms. The plant samples were sealed in paper bags and placed in a refrigerator at 40° F. for 48 hours to inactivate the thrips. Thrips were dislodged by striking the plants sharply against hardware cloth mounted on a frame which had been placed over a green desk blotter pad.

RESULTS.—*Dispersion studies, 1954.*—Results of dispersion studies on thrips in alfalfa fields are shown in figure 1. Members of the flower thrips group were active when traps were placed in the fields in early March. A gradual increase in dispersion occurred starting March 8. The peak of dispersion was reached during the period May 10 to 17. Small numbers of *F. exigua* Hood and *F. occidentalis* (Pergande) were trapped during April, May and June.

The tobacco thrips was first recorded from a trap on March 28. Dispersal reached a peak on April 12. Collections of this species remained small throughout the season.

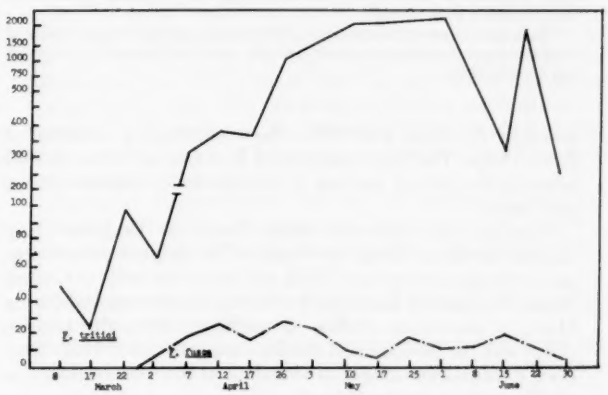

FIG. 1.—Average number of adult thrips per square foot on three Tanglefoot traps located in alfalfa fields, Burleson County, Texas.

Dispersal and populations of flower and tobacco thrips in bur and sweet clover roughly approximated those in alfalfa.

Dispersion Studies, 1955.—Trapping operations were discontinued June 30, 1955. Results were essentially the same as in 1954 except that collections of tobacco thrips were reduced and larger numbers of *F. exigua* were taken. The numbers of flower thrips trapped remained approximately the same during the seasons of 1954 and 1955.

Population Studies on Cotton, 1954.—Data on thrips populations studies in five cotton fields are shown in table 1. Although flower thrips were more numerous on the traps, tobacco thrips were predominant on seedling cotton. Only 10% of the total number of adult thrips taken from cotton during the first 6 weeks of growth were members of the flower thrips group. A reversal of species predominance occurred on cotton during June and members of this group accounted for 80% of the total number of thrips.

Population Studies, 1955.—During 1955 records were obtained on cotton from emergence to 6 weeks of age. Of the total number of adult thrips taken, tobacco thrips accounted for 59%, fol-

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[2] Assistant Professor and Professor, respectively.

Table 1.—Seasonal abundance of *Frankliniella fusca* (Hinds) and *F. tritici* group on cotton in Burleson County, Texas.

Field Number	*F. tritici* Number	*F. tritici* Per Cent of Total	*F. fusca* Number	*F. fusca* Per Cent of Total
Seedling Cotton (1 to 6 weeks old)[a]				
1-A	10	7	122	93
4-A	4	11	32	89
5	1	1	72	99
5-A	3	7	43	93
6	10	26	28	74
Maturing Cotton (6 weeks old to maturity)[b]				
1-A	179	64	102	36
4-A	90	79	24	21
5	9	100	0	0
5-A	38	66	20	34
6	37	100	0	0

[a] Each figure represents an average of six records on the average number of adult thrips on 20 plants taken at weekly intervals beginning when cotton plants emerged from the soil.

[b] Each figure represents an average of nine records on the average number of adult thrips per 20 plant parts taken at weekly intervals beginning when cotton was 6 weeks of age.

lowed by *F. exigua* with 38%. The remaining 3% consisted of flower thrips. The larger numbers of *F. exigua* on cotton in 1955 reflected the general increase of this species on legumes during that period.

SUMMARY.—In dispersion studies based on Tanglefoot trap records, the flower thrips was found to be the predominant species of thrips moving from alfalfa and bur clover fields in Central Texas. The peak of dispersion for this species was reached during May. In population studies on seedling cotton, the tobacco thrips was the predominant species during 1954 and 1955; however, *F. exigua* was almost as abundant as the tobacco thrips on seedling cotton during 1955.

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Ecological Studies of Spider Mites Attacking Cotton in Central Texas[1]

B. G. HIGHTOWER and DIAL F. MARTIN,[2] *Texas Agricultural Experiment Station, College Station*

Spider mites are pests of considerable importance throughout the cotton-growing areas of Texas. During 1954, a study was made of the host plants, population concentrations and dispersion movements of two species of spider mites common to Central Texas. The desert spider mite, *Tetranychus desertorum* Banks, is the most widespread and abundant species in Texas (Iglinsky 1951). However, *T. telarius* (L.) (two-spotted spider mite), *T. canadensis* McG. (four-spotted spider mite), and *T. schoenei* McG. (Schoene spider mite) also occur in this area.

EXPERIMENTAL PROCEDURE.—A preliminary survey was made to locate infestations of spider mites on winter host plants. Plants found harboring mites were marked with stakes and weekly spider mite infestation records were made on the selected plants. Infestation records were based upon the total number of adult and immature mites on 10 leaves taken at random. Counts were made in the field with the aid of a hand lens; however, samples of mites were taken at each examination and mounted for specific determination. All the host plants included in this study were identified by Dr. John Sperry of Texas A. & M. College.

RESULTS.—During February, small isolated colonies of the desert spider mite were found on evening primrose (*Oenothera* sp.), sow thistle (*Sonchus asper* (L.) Hill), horehound (*Marrubium vulgare* L.) and *Verbena bipinnatifida* Nutt. Plants protected by a cover of dead Johnson grass proved most attractive as winter host plants of this mite. Heavy populations of desert spider mites occurred on bur clover (*Medicago hispida* Gaertn.) during mid-March. Maximum reproduction occurred in localized areas on bur clover, usually in patches 2 or 3 feet in diameter. Clover plants in these areas were covered with webs and severely damaged. During the last week in April, large numbers of mites moved from bur clover to bloodweed (*Ambrosia aptera* (DC.)) and seedling cotton. These transfers occurred where the new host plants were in the same vicinity as the clover beds, usually only a fence-row or road separated the old hosts from the new. Spring rains were very detrimental to spider mite populations on cotton during this time and many infestations disappeared. Maximum rate of reproduction of the desert spider mite on cotton occurred during July.

The principal seasonal host plants and populations of the desert spider mite are shown in table 1. Infestations were also found during the summer months on horsemint (*Monarda* sp.), tievine (*Impomoea* sp.) and Johnson grass (*Sorghum halepense* (L.) Pers.). Cocklebur (*Xanthium* sp.) was the principal host plant of these mites during October. During November and December the mites moved from cocklebur back to the winter host plants. In some instances mites passed the winter on isolated patches of evening primrose and sow thistle in cotton fields.

Table 1.—Seasonal abundance of *Tetranychus desertorum* Banks on several important host plants examined in Burleson and Robertson Counties, Texas.

Host	Average Number of Mites per 10 Leaves[a] Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Evening Primrose	2	89	26	84	[b]				
Horehound	51	86	141	31	91	25	0	0	16
Bur Clover	0	99	108	31	[b]				
Bloodweed	0	23	25	12	124	27	69	13	3
Yellow Crownbeard	0	0	122	72	38	22	0	0	4
Cotton			12	12	84	197	100	26	1

[a] Each figure represents an average of 4 weekly records from 5 different areas.

[b] Plants died.

The principal host plants and seasonal abundance of the two-spotted mite (green form) are shown in table 2. Populations of this species increased slowly on all hosts before reaching a peak during July and August. The green form of this species was found only in association with ornamental plants during the winter and spring months. The red form of the two-spotted mite was found to overwinter principally on *Verbena bipinnati-*

[1] Technical Contribution No. 2387, Texas Agricultural Experiment Station in Cooperation with Entomology Research Branch, Agricultural Research Service, U. S. Department of Agriculture. Accepted for publication March 28, 1956.

[2] Assistant Professor and Professor, respectively.

Table 2.—**Host plants and seasonal abundance of *Tetranychus telarius* (L.) (green) in Robertson County, Texas.**

Host	Average Number of Mites per 10 Leaves[a]							
	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Rose	0	0	0.3	107	75	15		
Quince	0	0	0	75	50	20		
Cotton	0	0	0	45	66	56	11	1
Pear	0	0	0	0	0	12		
Bur Clover	3	0.5	0.5[b]					

[a] Each figure represents an average of 4 weekly records.
[b] Plants died.

fida Nutt. in mixed cultures with the desert spider mite. In several fields, red two-spotted mites were predominant on cotton during August and September.

Tetranychus canadensis occurred on bloodweed in considerable numbers throughout the spring months. During the summer, large numbers of this species were found on cocklebur. Five specimens of *T. canadensis* were collected from cotton in October. A damaging infestation of *T. schoenei* was found in a plum orchard adjacent to a cotton field but no specimens were found on cotton.

Dispersion.—The movement of the desert spider mite from bur clover to other host plants occurred during the latter part of April. Thousands of mites congregated in large masses on the tops of the clover plants and on the tips of nearby blades of grass at that time. In one area over 600 mites, mostly immature forms, were caught on a Tanglefoot trap placed 24 inches above the ground and 4 feet from the host plants. Dispersion of the mites over the entire surface of the trap indicated that they were carried into the trap by the wind. Large numbers of mites were also found crawling along the ground and on nearby plants during the period of dispersion.

Summary.—Evening primrose, sow thistle, horehound and wild verbena were found to be important winter host plants for the desert spider mite in Central Texas. Maximum populations of this spider mite occurred on bur clover in March and April; also, infestations were found on seedling cotton at this time. Summer hosts for this species included cotton, bloodweed, tievine and cocklebur. Maximum reproduction occurred on cotton during June and July.

Ornamentals were the principal host plants for the green form of the two-spotted spider mite while *Verbena bipinnatifida* Nutt. was the principal winter host plant for the red form.

Although *T. canadensis* and *T. schoenei* occur in this area they were of no consequence as cotton pests during this study.

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Control of Hornworms and Flea Beetles on Tobacco with Endrin and TDE[1]

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In Virginia the second brood of the tobacco hornworm (*Protoparce sexta* (Johan.)) and of the tomato hornworm (*P. quinquemaculata* (Haw.)) and the tobacco flea beetle (*Epitrix hirtipennis* (Melsh.)), are frequently a problem on late maturing tobacco. An effective dual-purpose insecticide that would give control of all three species with the same application would be highly advantageous. Allen *et al.* (1953) reported that endrin emulsion as a high-volume spray killed a high percentage of hornworm larvae and was quicker in lethal action than TDE. Dominick (1954) found that endrin applied as a low-volume spray gave a rapid reduction of the tobacco flea beetle at low dosages and was more effective than TDE. During 1955, an experiment was conducted to test the effectiveness of the currently recommended insecticides for hornworm control and to obtain further information on the use of these materials for flea beetle control under conditions where this insect occurs along with hornworms.

Procedure.—The plots were 0.1 acre in size, separated by three border rows, and arranged in randomized blocks. The dust treatments were replicated twice at two locations and the spray treatments three times at a single location. The dusts were applied on August 5 with rotary, hand-operated dusters at the rate of approximately 35 pounds per acre. The temperature at the time of application was 94° F. and the wind velocity was quite low. The sprays were applied on the same date at low-volume rates of approximately 11 gallons per acre with a boom-type sprayer equipped with *Tee-jet* nozzles. For each plot the results were determined by counting the number of third- to fifth-instar larvae on 50 tobacco plants; these consisted of 25 consecutive plants at each of two marked locations near the center of the plot. Counts were made before treatment and at 24- and 48-hour intervals following the dust or spray applications. The latter two instars predominated, and approximately 90% of the larvae present were the tobacco hornworm. Due to the low population of the tomato hornworm, and since the habits of the two species are similar, they are treated as a single species in this report. The flea beetle population was determined by counting all beetles on 10 randomly selected plants from the center row of each plot. Counts were made before treatment and 24 hours after treatment.

Results.—The materials used and the results obtained are presented in table 1. All three dust treatments gave effective hornworm control. TDE was slower in lethal action than endrin,

Table 1.—Control of hornworms and tobacco flea beetles on tobacco with endrin and TDE.

Insecticide	Actual Toxicant (Pounds Acre)	Hornworms			Flea Beetles	
		Number Before Treatment	Per Cent Reduction		Average Number per Plant Before Treatment	Per Cent Reduction
			24 Hours	48 Hours		24 Hours
Dusts[a]						
TDE 10%	3.5	41	83	96	19	93
Endrin 1%	0.35	38	88	95	24	98
Endrin 1.5%	0.525	37	91	96	23	99
Sprays[b]						
Endrin 19.5%	0.2	36	89	98	14	99
TDE 25%	1.0	37	80	98	18	68

[a] Average of 4 replications.
[b] Average of 3 replications. Emulsion concentrates were used.

but at the end of 2 days it gave a reduction similar to that of endrin. Endrin dust formulations at 1.0 or 1.5% concentrations gave similar reductions of hornworms. The per cent reduction of tobacco flea beetles at the end of 24 hours was slightly less for TDE than for the two endrin formulations. An observation made at one location 2 hours after the dusts were applied indicated that a high percentage of the beetles were dead in the endrin plots at the end of that period. It should be emphasized, however, that the temperature was quite high at the time the treatments were applied and probably influenced the initial kill of both hornworms and flea beetles. Approximately 0.2 inch of rain occurred between the initial and final hornworm counts.

As sprays, both endrin and TDE gave effective hornworm control. The initial reduction at the end of 24 hours for TDE

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was slightly lower than that for endrin, but both materials gave similar reductions at the end of 2 days. Endrin gave rapidly effective control of the tobacco flea beetle while TDE was much less effective.

SUMMARY.—Field tests for the control of hornworms and the tobacco flea beetle were conducted at Chatham, Virginia in 1955. Endrin as a dust or as a spray gave a higher initial kill of hornworms than TDE, but at the end of 2 days both materials were equal in effectiveness. TDE was less effective in controlling the tobacco flea beetle than endrin.

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Control of the Pine Spittlebug and the Pine Needle Miner[1]

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Both the pine spittlebug, *Aphrophora parallela* (Say) and the pine needle miner, *Exoteleia pinifoliella* (Chamb.), have become increasingly abundant in Rhode Island during recent years. The former insect began to increase in numbers in 1953, while the latter species became more numerous beginning in 1952. The pine spittlebug has been collected from pitch pine, Scotch pine, red pine and jack pine. The pine needle miner has been found on pitch pine and jack pine. Both insects have been particularly abundant on pitch pine and it was on this tree species that the studies reported herein were conducted under field conditions during 1955.

MATERIALS.—The insecticides and dilutions used in the experiments are listed in tables 1 and 2. All were wettable powders, and each dilution was applied with additional wetting, spreading and sticking agent[2] at the rate of 4 ounces in 100 gallons of water. The sprays were applied with a power-operated, hydraulic sprayer and spray gun.

PINE SPITTLEBUG.—In 1955, the first spittle and nymph was observed on May 11. Adults began to appear on June 27 and by July 1 were collected in relatively large numbers. On June 15, each dilution of insecticide was applied to five trees approximately 15 feet in height and infested with an average of 41 spittle masses with active nymphs per tree. Data on control were obtained on June 23, when the trees were examined for live nymphs. The data in table 1 show that all insecticides used were effective in controlling the insect.

PINE NEEDLE MINER.—The larval stage of the insect passed the winter of 1954–55 inside the pine needles. Feeding was resumed in late March, and by April 16 many larvae had migrated to and entered previously uninjured needles. Five per cent of them pupated by May 3, while 98% were pupae on May 16. Adults began to emerge on June 20 and were abundant on July 1. By July 12 a decrease in the number of adults was apparent, and on July 22 none could be found. Only one generation of the insect was observed during the 1955 season. This is in accord with the probability expressed by Craighead (1950).

Table 1.—Control of pine spittlebug with insecticides. Richmond, R. I. June, 1955.

INSECTICIDE W.P.	POUNDS IN 100 GALS. WATER	PER CENT CONTROL
50% DDT	2	95.1
50% Methoxychlor	2	100.0
25% Malathion	1	100.0
50% Dieldrin	1	100.0
25% Lindane	1	100.0
	0.5	100.0

Table 2.—Control of pine needle miner with insecticides Richmond, R. I. June–October, 1955.

INSECTICIDE W.P.	POUNDS IN 100 GALS. WATER	DATE APPLIED	PER CENT LEAVES MINED
50% Dieldrin	1	June 15	4.1
		June 27	5.7
		July 14	3.3
	0.5	June 27	8.2
		July 14	2.1
50% DDT	2	June 15	12.5
		June 27	8.8
		July 14	6.9
	1	June 27	11.8
		July 14	6.2
50% Methoxychlor	2	June 15	18.0
		June 27	10.5
25% Lindane	1	June 15	38.9
	0.5	June 15	27.1
Check	—	—	34.2

The sprays were applied on June 15 and 27, and July 14 using five trees approximately 20 feet tall in each treatment. During the period of September 20 to October 6, one hundred centimeters of twig containing approximately 2,000 needles of the current year's growth in each treatment were examined. The data in table 2 show that dieldrin was the most effective insecticide, particularly with regard to its residual action. DDT and methoxychlor were somewhat less effective in controlling the insect, while lindane was ineffective.

SUMMARY.—The biology and control of the pine spittlebug and the pine needle miner were investigated under field conditions during 1955. DDT, methoxychlor, dieldrin, lindane, and malathion were effective for control of the nymphal stage of the pine spittlebug. Dieldrin was more effective than either DDT or methoxychlor in preventing attack by larvae of the pine needle miner, while lindane was ineffective.

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[2] Triton B-1956, a modified phthalic glycerol alkyd resin.

The Use of Impregnated Paper as an Approach to Nutritional Studies with the Douglas-Fir Beetle[1]

J. A. CHAPMAN[2] and J. W. WILSON[3]

Little information is available on the nutritional requirements of scolytid beetles, although Hopf (1938) carried out some bark, frass and digestive enzyme analysis while studying a representative of this group. It is unlikely that they can digest cellulose (Day & Waterhouse 1953). The ingestion of paper by the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk., has been

[1] Contribution No. 256, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada. Accepted for publication October 24, 1955.

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reported (Chapman 1955). We felt that use of chemically defined papers to which various carbohydrates were added might provide information on the food requirements of this insect.

Three sets of paper hand sheets were prepared (TAPPI Standards 1953) from fractions of a dissolving grade western hemlock sulphite pulp. This pulp contained 95.5% α-cellulose, 2.0% β-cellulose 2.5% γ-cellulose, and 0.1% lignin by analysis. Set A contained α-cellulose only, set B contained α- and β-cellulose and set C was made from the initial pulp. The paper sheets were impregnated with starch, pectin, or one of the following sugars: d(−) glucose, d(+) mannose, d(+) galactose, d(−) ribose, or d(−) arabinose. Additives were uniformly distributed as 2 cc. of aqueous solution on the loose side of each sheet. Starch, though soluble, did not penetrate the paper well. Pectin could not be handled volumetrically and was applied by dipping sheets in a solution which provided approximately 0.5 g. pickup. Control sheets were treated with 2 cc. of distilled water. Treated papers were dried to constant weight at 70 to 73° C. and refrigerated until used. Before being placed with beetles, each of the sheets was crumpled into a loose ball and moistened with distilled water.

Most beetles used for this study were young adults taken during their bark feeding period but some were overwintered beetles, ready to fly. Tests were carried out at room temperature, and in darkness so that light intensity would not influence the distribution of beetles.

The beetles were tested on the impregnated papers in three different ways. First, 160 beetles were confined with control and additive papers of each set, for 2 to 4 weeks. Secondly, 300 beetles were placed for 10 days with a complete series of additive-paper combinations. Thirdly, 12 beetles were confined with one paper of each additive-paper type, and the survivors counted at intervals until mortality was complete.

The criteria used in evaluating effects of the additives were: extent of burrowing activity as shown by number of holes and amount of tearing of paper; location of live beetles at the conclusion of tests in which they had a choice of papers; numbers of feculae produced, as shown by examination of papers after removal of beetles; times for 50% and 100% mortality for beetles confined with single papers and total beetle-survival-days for these groups, determined by summing the products of the numbers of beetles and days during which they remained alive. It should be pointed out that a relationship between preference for carbohydrates and their effect on survival has not been established for this insect.

Although some of the data were inconclusive and the various criteria were not consistent in showing preference for specific carbohydrates, there were several indications that the beetles favored papers with additives over the controls. Pectin seemed to be least preferred. Set C appeared to be favored over A and B. No consistent differences were observed among any of the papers in number of holes or tears produced by the beetles.

Some representative data from the test are presented in tables 1 and 2 and results of analysis of the data in table 2 are briefly presented and discussed. Analysis of variance of the beetle survival data showed no significance for either additive or paper type. The percentages of loss of paper weight were transformed directly to angular values for analysis. Both additive and paper type differences were significant. Through removal of control and pectin treatments from further analysis non-significance occurred among the residual additives. This implies that the beetles showed a preference for any carbohydrate, but did not distinguish between them. Paper type remained significant in the subsequent analysis. Application of Student's "t" test showed significance as a result of A versus C, but not A vs. B, nor B vs. C. This implies that a trend of increasing acceptability exists as more of the pulp fraction is included.

As noted during earlier paper feeding observations, already cited, the beetles ate only small amounts of paper, as shown by feculae production and examination of intestinal contents, and did not continue to feed more than a few days. These papers were soft and contained little roughage compared with bark. They represented an unnatural food from both a physical and chemical standpoint. It is interesting, however, that certain bark beetles will readily burrow into sunflower stem pith soaked in sugar solutions (Merker 1953), and that the Douglas-fir beetle will feed on a glucose solution (Fang & Allen 1955). If a nutritionally inert carrier can be found with physical characteristics such that beetles will readily ingest it, if sugars or other food materials are added, it is likely that more conclusive studies could be carried out on bark beetle nutrition.

Table 1.—Location of beetles and number of feculae (six-minute examination) after exposure of additive-papers A, B, or C to 160 beetles.

	Location of Beetles			Number of Feculae		
	Type of Paper			Type of Paper		
Additive	A	B	C	A	B	C
Control	2	1	2	1	0	0
Glucose	0	3	10	22	11	32
Mannose	2	1	13	2	5	1
Galactose	0	2	18	14	35	6
Ribose	5	1	11	12	6	29
Arabinose	3	0	6	5	9	111
Starch	1	1	10	3	2	41
Pectin	0	3	2	0	2	29

Table 2.—Loss of paper weight and summed beetle-survival-days when 12 beetles were confined with each additive-paper type.

	Per Cent Loss of Weight			Beetle-Survival-Days		
	Type of Paper			Type of Paper		
Additive	A	B	C	A	B	C
Control	2.2	3.0	.8	179	235	219
Glucose	28	19	13	336	292	313
Mannose	23	13	19	187	241	325
Galactose	19	13	16	329	232	311
Ribose	14	7.5	7.4	288	258	235
Arabinose	25	20	17	339	196	254
Starch	19	24	6.9	256	270	232
Pectin	2.6	4.2	4.3	200	261	267

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EDITORIAL

Leadership and Service

Since the success, effectiveness and the general welfare of any organization depends to a very large extent upon the ability and devotion to service of its leaders, the procedure by which members of the Governing Board and the officers of the Entomological Society of America are selected should be a matter of grave concern to every member of the organization.

The presently prescribed procedure for the selection of the President-elect, while laudably democratic and soundly applauded by many, has been subjected to considerable criticism by some of our members. There are those who feel that our elections are to a considerable extent popularity contests and that under our present system many candidates possessing superb qualifications for the office have little chance of being elected when in competition with candidates having a much wider acquaintance. Thus many extremely capable men not so well known to many of our members have been or may be eliminated from further consideration on the first ballot. Still others suggest that with 8 to 12 names on the first ballot it is inevitable that where two or more strong candidates would derive their principal support from the same segment of the membership they would split the vote and eliminate each other and permit perhaps less qualified individuals to progress to the run-off ballot. A few even imply, we hope without justification, that such tactics have been deliberately employed. Then, too, there are many who feel that some sort of rotation system should be established whereby the office of President could not be monopolized by any single segment of the Society.

The writer is in sympathy with this point of view but is totally bewildered by the complexity and ramifications of the problem. Each of the subject matter interests—basic entomology (taxonomy, morphology, physiology, toxicology, biology, ecology, etc.) and applied entomology (medical entomology, crop pests, chemical control, biological control, extension, plant quarantine, etc.)—desires recognition and eventual representation in the list of Past-Presidents. Likewise, there are those who propose some suitable system of rotation as to geographic areas and nature of employment (state, federal, universities, industry, etc.). Spokesmen for each of these many diverse interests can present a sound and plausible argument in behalf of their constituents.

With so many diverse interests involved and so many specific proposals advanced, one is led to wonder whether or not it is possible to establish a workable system of rotation which would be acceptable to all or even a substantial majority and which would at the same time best serve the interests of the Society as a whole. Nevertheless, since there is such a diversity of opinion, perhaps the Society, in any revision of its Constitution, would do well to consider replacing the present procedures with a provision that the Governing Board or some other small body selected by equally democratic processes should serve as a nominating committee to screen all proposed nominations and limit the field to a few names, perhaps two or three, to be voted upon by the entire membership in a single mail ballot. Such a procedure would make it possible for the duly designated nominating body to critically review the credentials and record of all nominees and select a slate of candidates eminently qualified to fulfill the duties of this high office and perhaps at the same time institute some plausible system of rotation which would provide a reasonable guarantee that no single specialized interest or clique could monopolize the presidency. On the other hand, our current procedures have not worked too badly, and perhaps the fears expressed are quite unfounded. It is quite possible that if or when gross inequities develop the law of natural compensations will come into operation as it does in the ecological field. Thus, if any segment of the Society attempted to assume a position of dominance through sheer force of numbers or political influence, such sociological factors as resentment, sense of propriety, and justice would come into play and reduce that segment to its appropriate level. It is not improbable that such forces are even now in operation and in the long run they might be more effective than rules or regulations.

Election to the Presidency of the Entomological Society of America bestows upon the recipient a signal honor that cannot be measured in tangible units, but it likewise imposes upon that same recipient duties and obligations the magnitude and gravity of which are perhaps fully known only by those who have served in that capacity.

The President of the Entomological Society of America is the chief administrative officer of a corporation with an annual budget in excess of one hundred thousand dollars ($83,000.00 cash and at least $25,000.00 in donated services). It is more or less taken for granted that any candidate for president should have attained a degree of professional distinction in some phase of entomology and science in general that will command the admiration and respect of our colleagues in other branches of science as well as in our own Society. In addition, the very nature of his duties presupposes that he will possess administrative ability, good business judgment, ability to give and take, an untarnished reputation, a sense of justice when considering minority wishes and needs, and last but not least a sense of humor. Add to these requirements the fact that as matters now stand it is almost imperative that the president have at his disposal office facilities and a staff that can be imposed upon to handle the extensive correspondence inherent in the conduct of the office, and you have a cross section of the prerequisites of this important office. It is doubtful if one would ever find perfection in all of these attributes combined in any one individual, but that should be our objective.

In the case of the Governing Board, the Constitution has made provisions for reasonably satisfactory representation of specialized subject-matter interests and at

least some geographic distribution, but here again while selecting men of unquestioned ability, there is an ever-present danger that we may overlook an important prerequisite of the office. Since the Governing Board transacts most of its business at sessions held immediately before, during, and immediately after the annual meetings of the Society, an individual who does not almost habitually attend annual meetings is not apt to serve with the utmost effectiveness as a member of the Governing Board.

Certainly every member who possesses the desired qualifications should have an equal opportunity to be selected for the supreme honor our Society can bestow upon him, namely the presidency of the Entomological Society of America, or to serve with distinction on its Governing Board, regardless of his chosen field of specialization or the nature of his employment. At the same time, consistent with the sentiment expressed in his presidential address in December, 1955, the writer would urge that for the time being, at least, in the selection of our officers and members of the Governing Board we should be primarily concerned with the specific qualifications of the candidates and the prerequisites of the office in question and much less concerned as to the candidates' age, sectional affiliation, or field of special interest. To this end may we again dedicate ourselves to the proposition that "In union there is strength," and regard all of our members as dedicated to a common cause, the welfare of entomology.

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Interval Between Oak Wilt Fungus Inoculation by *Drosophila melanogaster* and Appearance of Foliar Symptoms[1]

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Seventeen instances of oak wilt fungus transmission by the pomace fly, *Drosophila melanogaster* Meig., resulted from tests made during 1953 and 1954. Fungus transmission was obtained by allowing flies to feed first upon the small globules of moisture formed at the tips of hyphae on sporulating mat cultures of *Endoconidiophora fagacearum* Bretz producing endospores only, and then upon fresh xylem wounds made artificially in healthy oaks. It seems probable that most of the 17 oaks were inoculated with the fungus on the first day they were placed under test when the wounds were fresh, since wound feeding activity of the flies was greatest during that period. Of the 17 oaks that developed oak wilt symptoms, 16 were potted seedlings 2 to 4 years of age which were kept out-of-doors in a screened cage before and after being placed under test, and one was a woodland tree approximately 40 years of age. The presence of the oak wilt fungus in all of the 17 symptomatic oaks was verified by culturing.

The 17 oaks were placed under test at various times of the year between spring and fall and 13 of them developed oak wilt foliar symptoms the same year they were tested (Griswold 1953, 1955). However, the other four oaks did not exhibit such symptoms until June of the following year. It is notable that one of these four oaks had been exposed to a severe frost the day before it was placed under test. Thus the tests revealed a wide period of inoculation by *D. melanogaster* and a broad variation in the interval between inoculation and the appearance of foliar symptoms. The data concerned in the study are summarized in table 1.

Table 1.—Interval between oak wilt fungus inoculation by *Drosophila melanogaster* and appearance of foliar symptoms.

Date Oaks Placed Under Test	Oak Species	Oak Age in Years	Date Foliar Symptoms Appeared	Days Between Probable Time of Inoculation and Appearance of Foliar Symptoms
April 25, 1953	Red	2	July 5, 1953	71
April 1, 1954	Scarlet	40	June 2, 1954	62
July 7, 1954	Red	3	Aug. 13, 1954	37
July 7, 1954	Red	3	Aug. 17, 1954	41
July 8, 1954	Red	3	July 26, 1954	18
July 8, 1954	Red	3	Aug. 13, 1954	36
July 10, 1954	Scarlet	3	July 30, 1954	20
July 10, 1954	Red	3	Aug. 19, 1954	40
July 19, 1954	Red	4	Sept. 20, 1954	63
July 19, 1954	Black	3	Sept. 26, 1954	69
July 20, 1954	Red	3	Aug. 17, 1954	28
July 20, 1954	Red	3	Sept. 7, 1954	49
July 21, 1954	Swamp White	4	June 16, 1955	330
Aug. 2, 1954	Red	3	Sept. 19, 1954	48
Sept. 4, 1954	Red	3	June 20, 1955	289
Sept. 26, 1954	Red	3	June 20, 1955	267
Oct. 8, 1954	Red	4	June 8, 1955	243

DISCUSSION.—From the results of the study it was apparent that *D. melanogaster* inoculated healthy oaks with the oak wilt fungus over a wide period from early spring until after the first severe frost in the fall. It was also evident that there was a wide variation in the interval between the time of probable fungus inoculation and the appearance of foliar symptoms. The variation ranged from 18 to 71 days in the oaks that developed symptoms the same year they were placed under test and from 243 to 330 days in those that did not develop such symptoms until the following year.

Among the oaks that developed symptoms the same year, a considerable degree of variation was also observed between the time of inoculation and appearance of symptoms in oaks placed under test the same day. Conversely, the oaks that did not develop symptoms until the following year exhibited them within a relatively short period of 13 days in mid-June, although they were placed under test over a period of 80 days between July 21 and October 8 the previous year. Thus it may be inferred from the study that oaks in the field may be susceptible to oak wilt fungus inoculation from early spring until fall and that at least some of them found developing foliar symptoms during June may have been inoculated the previous year.

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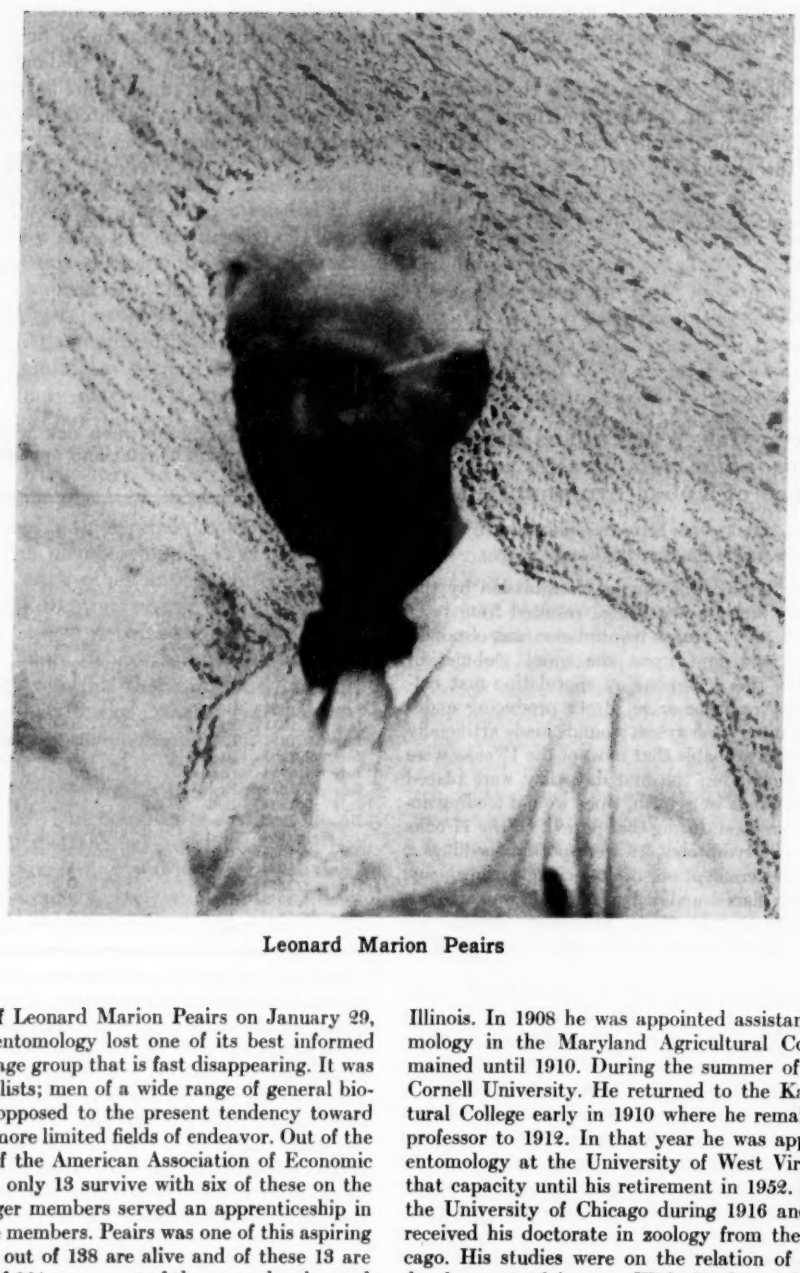
OBITUARY

Leonard Marion Peairs
1886-1956



Leonard Marion Peairs

With the passing of Leonard Marion Peairs on January 29, 1956, the science of entomology lost one of its best informed leaders. He was in an age group that is fast disappearing. It was also a group of naturalists; men of a wide range of general biological knowledge as opposed to the present tendency toward high specialization in more limited fields of endeavor. Out of the 126 active members of the American Association of Economic Entomologists in 1911 only 13 survive with six of these on the retired list. The younger members served an apprenticeship in those days as associate members. Peairs was one of this aspiring group. Today only 20 out of 138 are alive and of these 13 are retired. In this group of 264 were most of the men who elevated economic entomology to the prominence it enjoyed, worldwide, for many years.

His father was a teacher and supervisor of Indians and Leonard was born in Lawrence, Kansas on June 5, 1886. He graduated from Kansas State Agricultural College at Manhattan in 1905. He was a graduate assistant there from 1905 to 1907 and received his master's degree in that year. From 1907 to 1908 he served as a graduate assistant in the University of Illinois. In 1908 he was appointed assistant professor of entomology in the Maryland Agricultural College where he remained until 1910. During the summer of 1909 he studied at Cornell University. He returned to the Kansas State Agricultural College early in 1910 where he remained as an assistant professor to 1912. In that year he was appointed professor of entomology at the University of West Virginia and served in that capacity until his retirement in 1952. He was a Fellow in the University of Chicago during 1916 and 1917. In 1925 he received his doctorate in zoology from the University of Chicago. His studies were on the relation of temperature to the development of insects. With Sanderson he published in the JOURNAL OF ECONOMIC ENTOMOLOGY in 1914 "The relation of temperature to the development of insects" and in 1927 published alone Bulletin 208 of the West Virginia Experiment Station, "Some phases of the relation of temperature to the development of insects." This bulletin reported a mass of data in support of the straight line theory of the velocity of development.

He collaborated with Sanderson on the revision of "Insect

Pests of Farm, Garden and Orchard" in 1921 (first published by Sanderson in 1912), and later revised this text under the same title in 1931; a third revision in 1941 bore his name as sole author. The writer was the recipient of an inscribed copy, To E. N. Cory from L. M. Peairs, 1908–1941. In publishing herewith the letter of transmittal that accompanied the gift, I am sure my readers will understand that it is done merely to give an insight into the modest mind of the one who wrote the letter and to give some slight indication of the quality of his friendship.

My dear Cory:

Under separate cover I am mailing a copy of Insect Pests. I wished to insert a suitable inscription but found that I was entirely unable to put into words the sentiments which I would like to express. I believe that you know what they are and will trust that you will always be able to read them between the lines in all our relationships. And one of my real sources of satisfaction is the feeling that the sentiments are mutual.

Cordially yours,
L. M. Peairs

Peairs served as editor of the JOURNAL OF ECONOMIC ENTOMOLOGY from 1940 to 1953. For this task he was especially qualified as he was conversant with mathematics, physics and chemistry, in addition to his extensive knowledge of entomology and his exact knowledge of rhetoric. He gave of his knowledge, time and energy without stint. He drove himself relentlessly in this work, which was a "labor of love," as he felt he had a service to perform to the American Association of Economic Entomologists. In fact, he exhausted his slim physical resources, demonstrating to all who knew the facts his outstanding unselfishness towards his fellow scientists.

He was a life member of the American Association of Economic Entomologists, an honorary member of the combined Societies, the Entomological Society of America, and recipient of a watch from that Society "for long and meritorious service as Editor," fellow of the American Association for the Advancement of Science, Sigma Xi, Alpha Zeta and Phi Kappa Phi.

He was married in 1915 to Edith Pennington, who survives him. There are two children, C. A. Peairs who is a professor of law in Boston University and a daughter Dorothea, Mrs. G. W. Monk, of Frederick, Maryland.

E. N. CORY

Pleocoma oregonensis Leach[1] as a Pest in Sweet Cherry Orchards[2]

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In September, 1953, grubs of *Pleocoma crinita* Linsley were discovered feeding on roots of apple and pear trees in the Hood River Valley, Oregon. As a result of the root feeding, many pome fruit trees are declining in vigor (Ritcher & Olney 1953). This report presented the possibility of another species of *Pleocoma* occurring in the stone fruit growing district at the Dalles, since one species, *P. oregonensis*, is recorded occurring at Wasco, Oregon (Linsley 1938). Subsequently, three male beetles of *P. oregonensis* were taken during flight in a cherry orchard near The Dalles in October and November, 1953.

The first indication of grub damage to cherry trees occurred in early March, 1954, when a cherry grower at The Dalles removed 26 dead or dying Bing trees. Examination of the exhumed roots disclosed feeding injury and *Pleocoma* grubs were found intermingled with the soil clinging to the roots. The feeding injury was in the form of deep winding grooves, often girdling the roots.

Intensive digging in March and April, 1954, disclosed large grubs actively engaged in feeding on varied size roots of sweet cherries. The smaller grubs were found in close association with rootlets and root hairs. In mid-September, the large grubs were in cells and not feeding on roots. Measurements of the vertical distribution disclosed that the grubs were dispersed from a depth of 8 to 37 inches in the soil beneath cherry trees.

Adult males began flying on October 8, 1954, during the first rain of the fall season. The flight of *P. oregonensis* males takes place at two time intervals in the day. Activity may begin at 6:30 A.M. or again late in the afternoon about 4:30 P.M., eithe in the rain or with only an overcast sky and a saturated atmosphere. The peak of male activity occurs in October and November.

One or more males may be found entering a burrow occupied by a female. In a number of instances, seven to nine males have been found burrowing down to a female beetle, with two or more males being crushed in the process. During October and November, the females are usually within 5 inches of, or often just beneath, the soil surface.

Two females were mated in November, 1954, and placed individually in soil cages 4 feet in depth. The cages were examined in mid-July, 1955, and in both instances, the females had burrowed to the bottom of the cages. One female deposited 35 eggs and the other 48. Egg hatching began July 25, and continued until August 2, 1955.

Adult beetles have been found in quite varying habitats. At The Dalles, concentrations have been located in two cherry orchards and in a pure stand of western yellow pine. Another concentration is located in sagebrush grassland, 15 miles east of Wasco, Oregon.

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[1] Determination by Drs. E. Gorton Linsley and J. W. McSwain, University of California, Berkeley, California.

[2] Accepted for publication March 27, 1956.

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